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DARK-ADAPTATION AND THE PERIPHERAL COLOUR SENSATIONS OF NORMAL SUBJECTS

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Introduction

THOMAS YOUNG, in 1800, appears to have made the first careful observations on the sensitivity of the peripheral retina. In his own words: "The visual axis being fixed in any direction, I can at the same time see a luminous object placed laterally at a considerable distance from it; but in various directions the angle is very different. Upwards it extends to 50 degrees, inwards to 60, downwards to 70, and outwards to 90 degrees. These internal limits of the field of view nearly correspond with the external limit formed by the different parts of the face, when the eye is directed forwards and somewhat downwards, which is its most natural position." It is clear that Thomas Young was fully aware of the limitation of the field of vision by the features. If precautions are taken it can be shown that the field of vision has the form of an ellipse with its long axis horizontal and with the blind-spot in its centre (Basil Lang).

A few years later Troxler (1804) found that when coloured papers are moved towards the periphery, certain colours are recognisable at a greater angle than others. Purkinje (1825) confirmed and extended the observations and since that date over 100 papers have been published dealing with peripheral vision. The chief

reason for this abundance of papers is that the results of the work appear to contradict the Young-Helmholtz theory of colour vision whilst they favour, on the other hand, the Hering theory. In the consideration of the results their relation to the duplicity theory of v. Kries should be borne in mind. The attitude of the adherents of the Young-Helmholtz theory to the duplicity theory has never been very clearly defined and this aspect of the subject has not been given the attention it deserves. The aim of this thesis is to present some evidence which may help to bridge the gap. Although the results add but one more paper to an already overcrowded literature, they may be useful in that they emphasise the necessity of controlling certain factors in work on the peripheral retina.

Historical

Purkinje (1825) described the changes in hue when a coloured stimulus is moved in from the periphery. All coloured objects appear grey or black when their images fall on the extreme peripheral retina and pass through regular transitions of colour tones as their images approach the fovea. It is probable that Purkinje used coloured papers but he defined neither their area, the amount of light falling on them nor their background. The experiments have been repeated by many workers and their results mostly confirm those of Purkinje.

The results vary slightly with the type of stimulus colour used, and most of the recent work has been done with either spectral colours or filters, it being impossible to get even approximately pure colours with the use of coloured papers. The hue changes are substantially the same whichever type of stimulus is used and all workers agree, in general, on the following changes in hue when the stimulus is viewed with increasing obliquity.

Red soon becomes orange, then yellow, yellow-brown and finally black (or grey if viewed on a black background). Orange passes through yellow to grey. Yellow becomes more and more desaturated and finally appears grey. Green passes through yellow to grey. Blue becomes desaturated and finally appears grey. Violet passes through blue to black. Purple becomes violet-blue and finally grey. In the extreme periphery colours appear grey or black; in the intermediate zone the long wave-lengths appear yellow and the short wave-lengths blue; in the inner zone the hue passes along the spectrum and finally comes to rest at its true colour. From this it follows that there will probably be a wave-length in the yellow and one in the blue which will not change in hue. There will also probably be a wave-length in the green which passes neither through yellow nor blue

to white and will appear green at all points of the retina. Add to this green its complementary purple and we have four colours which should undergo no hue changes when viewed peripherally. These colours were shown to exist by Bull (1881) and Hess (1889) and are known as the invariable colours. Hess gave their wave-lengths as: yellow 574·5$\mu\mu$, blue 471$\mu\mu$, green 495$\mu\mu$ and the red-purple complementary to the green.

In text-books on the subject there is often to be found a diagram giving the exact position on the peripheral retina at which red, green, blue and yellow can be recognised. It is important to remember that these diagrams were obtained from invariable colours. It is a waste of time to map out a colour field unless this precaution is taken, otherwise the phenomena of peripheral hue changes described above will be obtained. In the usual statement of the phenomena, red and green are described as losing their colour simultaneously and yellow and blue also simultaneously but farther out in the peripheral retina. This statement also needs qualification since it is obviously absurd to compare the field of vision for a bright red with that of a dull green. It is necessary that the colours should have the same " white-valency," that is, that their luminosities measured by heterochromatic photometry should be the same. Provided complementary colours of the same brightness are used, the fields of vision for red and green are coincident. The fields of vision for yellow and blue also coincide with one another, but they are more extensive. At the extreme periphery of the retina there is a zone where all objects are seen in shades of grey (Hess 1889, Hegg 1892). The importance of this phenomenon to the Hering theory of colour vision will be considered later. Guillery (1896) measured the smallest coloured areas which could be recognised by the peripheral retina. His results confirm those of Hess by an entirely different method.

Dreher (1911) investigated peripheral colour sensations in a different way. He used two monochromatic spectral patches, one seen by the fovea and the other seen by the peripheral retina. The wave-length of the peripheral patch was varied so as to appear of the same hue as that of the fovea. No very definite conclusions were reached except that a yellow appears redder when seen peripherally than when seen by the fovea. From this author's results it is clear that a subject will call a much wider stretch of the spectrum yellow when viewed by the periphery. No worker appears to have measured the just noticeable difference of hue in different parts of the spectrum for the peripheral retina.

The experimental difficulties of investigation in the peripheral retina are very great and it cannot be said that they have been very adequately controlled in work up to the present. Considerable attention has been paid in the past to those factors which are

known to influence the colour fields. This work is important since it is possible that some of the phenomena of peripheral colour vision have their origin in causes other than the differential sensitivity of the retina to colour.

The peripheral colour fields are enlarged in an orderly manner by an increase in the brightness of the retinal image (Abney 1913 p. 203) and provided it is bright enough, colours can be recognised by the extreme peripheral retina (Landolt,1873). The brightness of the retinal image is regulated by the pupillary diameter and the angle which the incident light makes with the plane of aperture of the pupil. It is of importance to prove, therefore, that the differential sensitivity of the retina to colour is due to neither of these physiological conditions (Landolt, 1874). Ferree and Rand (1916) controlled both these factors by passing their test-lights in a narrow pencil through the centre of the pupil and they showed that the phenomena of peripheral colour vision still held.

The general effect of increasing the size of the coloured test-object is the same as that of an increase in the illumination (Charpentier, 1877, Abney, 1913). Abney found that for all colours the average diminution in field on cutting down the intensity by one quarter was 7·5 degrees, whilst an increase in the area of the test-patch by one quarter led to an increase of five degrees. The optical system of the eye suffers from the defect of chromatic aberration, the result of which will be that the area of retina illuminated will vary according to the colour of the stimulus. It will be noticed that the increase in the field of vision which would be brought about by this cause is very nearly compensated for by the diminution in the brightness of the retinal image, therefore fields of vision should be largely independent of chromatic aberration. Albini (1887) has claimed, however, that with a suitable correction for the chromatic aberration due to each colour and for the error of refraction of each part of the retina used, all colour fields are co-extensive. This worker also claims that lack of practice in everyday life is a factor to be taken into account in the consideration of the poor colour discriminations of the peripheral retina. Subsequent workers do not appear to have confirmed Albini's observations.

From the physiological point of view there is another factor of great importance in certain types of colour-vision experiment, namely the presence within the eye of coloured pigments other than those concerned directly with perception. The influence of macular pigmentation on colour matches at the fovea is too well known to need elaboration (Maxwell, 1860). The distribution of the pigment in the region of the fovea is very variable in different subjects. Its extent is usually determined by subjective experiment and it is not unusual to find unmistakable signs of its presence

10 degrees from the fovea, but beyond this, experimentation is difficult and complicated by the colour phenomena of the peripheral retina. Brücke (1851) has shown that the colour sensations of the retina can also be modified by the presence of haemoglobin within the eye. Although very little attention has been paid to this observation, it will be shown later that it may have a bearing on peripheral colour sensations.

Theoretical

The chief arguments against the Young-Helmholtz theory of colour vision are supplied by the changes in colour sensation in the peripheral retina. According to this theory the coloured retinal image excites three mechanisms which, for the sake of illustration, can be assumed to be three types of cone, each type responding to different wave-lengths. The character of the sensation depends on the extent to which these three cones are stimulated and this depends on the wave-length composition of the stimulating light.

According to this theory the sensation, yellow, results from approximately equal stimulation of the red and green receptor cones. When, however, a red light is viewed more and more peripherally, it looks first orange and then yellow. This phenomenon could be explained by assuming that the " green " cones and the " red " cones are being stimulated unequally, the retina having become partially red-blind. This was Helmholtz' (p. 373) explanation, but it is unlikely because a green light viewed peripherally also looks yellow.

If the peripheral retina were red-blind and if white results from equal stimulation of a red, a green and a blue receiving cone, then a white object should appear blue-green peripherally (Berry, 1920). The fact that such a phenomenon does not occur, indicates that if the peripheral retina has become partially blind to red it must also have become equally blind to the complementary colour, namely blue-green. To explain the result in terms of the theory, therefore, one must say that the peripheral retina loses sensitivity to colour in such a way that complementary colours are equally affected. This is precisely the result obtained by Hess in his investigation on colour fields and it may also be explained by Hering's theory.

" Hering regards the whole series of our visual sensations as made up of six primary sensations: but the most novel and fundamental feature of his theory is the arrangement of these six sensations in three pairs, the two members of each pair being antagonistic in nature to each other, and depending on physiological processes of an opposite kind. Each of the three pairs of sensations depends on the action of a special substance, the three

substances being called black-white, red-green, yellow-blue. In most kinds of stimulation of the retina all three substances are set in action, and the character of the sensation is determined by the relative amount of action of each." (Rivers, 1900). The red and the green of the red-green substance are complementary, and the diminution of colour sensitivity in the near peripheral retina is explained as a partial or complete absence of this substance. If this is the true explanation then white will still appear white when viewed indirectly.

It has been shown by Landolt (1873) and v. Kries (1897) that vision in the peripheral retina is to be regarded as central vision diminished in sensitivity and that this also applies to the extreme periphery. v. Kries determined the peripheral luminosity values of various spectral lights and compared them with the corresponding values for night vision in the region of the fovea. Provided the eye is light-adapted the luminosity curve in the extreme periphery has its maximum at 608$\mu\mu$ and this roughly corresponds with the maximum for day vision at the fovea. This phenomenon is not to be explained by either of the rival colour vision theories in their original form. Both these theories consider that the peripheral retina of the normal eye shows the same conditions as are found in colour blindness. The Young-Helmholtz theory explained the achromatic vision of the extreme peripheral retina of the normal eye by assuming that in this region all the colour perceiving cones are absent and vision is served by the rods or the organs of night vision. The Hering school assumed that only the black-white substance is present, namely the receptor for night-vision. If either of these were the right explanation, then the peripheral luminosity curve would be the same as that for night vision and also the same as that for the condition of total colour blindness. In view of the work of v. Kries neither of these can be the right explanation.

In order to make the results harmonise with the Young-Helmholtz theory certain assumptions are necessary and the hypothesis of Fick (1890) offers a fairly good explanation. Fick assumed that the colour sensation curves become flatter as the periphery of the retina is approached, the change first affecting the green and red curves, which ultimately coincide. If the three-colour sensitivity of the cones depended on their containing an outer shell of three different coloured pigments, a dilution of these pigments would lead to a flattening of the curves. Another way of expressing the result in terms of broadcast reception would be to say that the colour receptors become less sharply tuned. This will have the effect of making hue perception in the peripheral retina blunter since a change in wave-length will not produce so great a change in the response of the colour receptor as it would

at the fovea. According to the hypothesis, the peripheral retina would be less selective than the fovea. In addition those colours containing inherent white at the fovea (Abney, 1913), would contain more of this inherent white in the periphery. Abney (p. 201) did in fact find that a yellow, wave-length 589$\mu\mu$, has a larger field of vision than a yellow made by mixing green, 527$\mu\mu$ and red, which produced an identical match with the spectral yellow at the fovea. Unfortunately this observation could also be explained by the greater scotopic (achromatic) value of the mixed light.

If true, another interesting consequence of this hypothesis would be that the total stimulation value of a uniformly bright retinal image would be higher in the periphery than at the fovea; subjectively white light would be brighter. The reason for this would be that the coloured shell of the cones would be more dilute in the periphery and the physical intensity of the light transmitted to the light-sensitive layer would be greater. No one appears to have undertaken the difficult task of putting this point to the direct test. It is known, however, that the critical frequency of flicker value is higher in the periphery than at the fovea for day vision. This fact cannot be explained by assuming that the rods are the elements responsible for the perception of flicker in the periphery (Lythgoe and Tansley, 1929 *a*).

The Young-Helmholtz theory is concerned only with the cones, the colour sensitive receptors of day vision. Adherents of the theory usually look on the rods as being pre-eminently the organs of night vision, capable of giving rise to only one type of colour sensation, that of bluish-white.

The fovea contains cones only: the peripheral retina has very few cones and many rods. According to the Helmholtzian view the sensations of the peripheral retina should be a mixture of colour sensations from the cones and a colourless sensation from the rods. Since the rods have very considerable powers of dark adaptation, the light threshold sensitivity rising about one thousand times during half an hour's stay in the dark, the resultant sensation and the peripheral luminosity curves are very profoundly modified by dark-adaptation of the eye (Hering, 1895, Tschermak, 1900). It is generally agreed that the character of the surrounds considerably modifies the colour sensations from the peripheral retina (Aubert, 1857), but some workers have denied that the background has any influence (Woinow, 1870; Krükow, 1874). Ferree and Rand (1920) have paid considerable attention to this point and always use a surround having the same brightness as the test-patch. It is often assumed that the influence of the surrounds is due to some type of simultaneous contrast. Another possibility should, however, be taken into account,

namely, that the effects may be due to the local condition of adaptation of the retina in the region of the test-patch. By surrounding the test-patch with black the rods might become dark-adapted and more sensitive and in this way dilute the colour by a colourless sensation.

In the consideration of the relation of the Young-Helmholtz theory to the duplicity theory, there is one outstanding point of great interest and that is the contribution of the rods to visual sensations at high illuminations (v. Kries, 1894, 1896). It is possible that the whole of their visual purple content becomes bleached, so becoming insensitive and playing no part in the peripheral luminosity values (v. Kries, 1897; Parsons, 1924, p. 215). Another explanation is that they have become "saturated," an increase in stimulus causing no increase in sensation. A third view is that the rods are the receptors for blue. Although there is no evidence for this suggestion it is attractive from some points of view, since it is not in keeping with our conceptions to think of a structure lying idle in the body as the rods would do if they were functionless at high illuminations.

Parsons (1927) has examined in great detail the histological evidence bearing on the duplicity theory. There is overwhelming subjective evidence of a dual mechanism of vision and superficially this seems to bear some relation to the relative distribution of rods and cones. There are, however, some very serious difficulties in the way of accepting the histological side of the theory, amongst which can be mentioned (1) the lack of uniformity in the shape of the rods and cones amongst different animals; (2) the rod-like shape of the "cones" in the human fovea; and (3) the paucity of cones in the human peripheral retina. Parsons is of the opinion that the number of peripheral cones is quite inadequate to explain colour vision in the periphery, the most serious objection being that the periphery has exactly the same characters as the fovea but to a less degree. Their photopic luminosity and colour mixing curves are the same and the peripheral curves show none of the characteristics of rod vision. To account for this Parsons advances the attractive suggestion "that under high intensities of excitation in normal man, the 'dyscritic' (night) mechanism is capable of giving the same chromatic responses as the cones, or essentially epicritic mechanism." (p. 177). If this view be adopted it is necessary to examine closely the evidence derived from dark-adaptation. During the course of dark-adaptation the dyscritic mechanism becomes increasingly sensitive. How is this accomplished? What is the fate of the epicritic mechanism after prolonged dark-adaptation and what is the fate of the dyscritic mechanism at high general levels of illumination? According to Parsons the responses of the peripheral retina

become almost entirely epicritic at high illuminations in the light-adapted eye, whilst the presence of dyscritic mechanism cannot be detected. During the course of dark-adaptation the responses of the peripheral retina become more and more of the dyscritic type and one would expect the epicritic mechanism to have become less sensitive. Instead of enquiring into the fate of the rods and cones at high and low illuminations respectively, if we follow Parsons we must continue the enquiry in terms of the dyscritic and epicritic mechanisms, both of which are served by the peripheral rods. The chief question to be answered is whether the responses of the peripheral rods become epicritic at the expense of the dyscritic mechanism and *vice versa*.

The Objects of the Experiments

The experiments to be described were designed with a view to finding the fate of day (cone or epicritic) vision during dark-adaptation and they were a continuation of some work on the changes in the critical frequency of flicker during the course of dark-adaptation (Lythgoe and Tansley, 1929, *a*). Several subjects took part in these experiments, readings being taken at many points on the retina. Since some of the results were difficult to explain, it was decided to make a parallel investigation on peripheral colour sensations. The points at issue were: (1) the differences in colour sensations between the light and dark adapted eye, and (2) the relative behaviour of the different subjects.

The conclusions drawn from the experiments on the critical frequency of flicker were that the highest perceptible rate of alternation of black and white increases during the course of dark-adaptation for the rods and decreases for the cones. The evidence advanced for these conclusions was as follows: There was a progressive fall in the critical frequency of flicker (1) at the fovea whatever the illumination of the flickering test-patch, and (2) with a red test-patch at all points on the retina. There was a progressive rise in critical frequency (1) when a faintly illuminated test-patch was viewed peripherally. (2) This phenomenon was more pronounced as the periphery of the retina was approached. The duration of the rise was about 45 minutes and was therefore comparable with the time occupied in the establishment of night vision as measured by the light threshold. At high illuminations of the test-patch the critical frequency measured by the periphery fell whilst at intermediate illuminations there was a quick fall followed by a long drawn-out rise.

There seemed no doubt that the rise in critical frequency due to the rods should be correlated with their increased sensitivity during dark-adaptation. A fall in critical frequency should

therefore be associated with decreased sensitivity. If this argument were applied to the cones it would indicate that they become less sensitive during dark-adaptation. A certain amount of evidence was collected to show that this is not improbable. Another factor, the swamping effect of the rods, probably modifies and might wholly account for the fall in critical frequency readings due to the cones. In the dark the sensation due to an illuminated area of the retina would be derived both from the cones and from the rods. Since the sensitivity of the rods increases so vigorously during dark-adaptation the resultant sensation would become more and more due to the rods during the stay in the dark. Applying this reasoning to the perception of a flickering test-patch, one could imagine conditions where the cones could, by themselves, appreciate the flickering whilst the rods' contribution to the resultant sensation would be a bright non-flickering sensation of light. During the course of dark-adaptation this non-flickering sensation might become sufficiently intense to swamp and to mask completely the flickering sensation from the cones. Since, however, the critical frequency at the fovea and with a red light at all points on the retina, both fall during dark-adaptation, it is highly improbable that the masking effect is sufficient in itself to explain all the phenomena. The final conclusion was that the cones become less sensitive during dark-adaptation.

The perception of a coloured stimulus by the peripheral retina might be influenced by these factors. The coloured stimulus in the light-adapted eye would stimulate the cones and give rise to a sensation of colour. In the dark-adapted eye this colour sensation would be diluted by a colourless sensation from the rods and in addition the sensation from the cones would become less intense if they became less sensitive.

In the experiments which are to be described an attempt has been made to compare the sensations evoked by coloured stimuli in the light and dark-adapted eyes. The main points which have been kept in mind are the desaturation of the colour and difficulties in colour recognition.

Apparatus

The apparatus was the same as that used in the experiments on the critical frequency of flicker. The subject sat inside a large whitened cube whose sides measured 152 cm. The test-patch was viewed through a square hole cut in the wall of the cube and subtending an angle of one degree at the subject's left eye. The advantages of this arrangement are that the whole of the subject's retina can be uniformly light-adapted by illuminating the walls of the cube and also that the subject can be instantaneously

plunged into complete darkness by switching off the light inside the cube.

The subject sat on a stool and rested his chin on a mould of dentist's wax. The mould was supported on a bracket hinged in such a way that horizontal movements of his head were about an axis passing through the observing eye, whose position in the cube therefore remained approximately the same. On the same horizontal plane as the test-patch and the observing eye were fixation points on the wall of the cube making various angles between the test-patch and the eye. If the subject fixated the 30° degree mark, then the retinal image and the fovea subtended an angle of 30 degrees at the nodal point of the eye. Streaks of luminous paint served as fixation marks when the subject was in the dark. Only the horizontal meridian of the left retina was explored and vision of the test-patch by the right eye was prevented by adhesive tape on the side of the nose.

The test-patch outside the cube was of matt-surfaced opal glass and, to the subject, it appeared to fill the opening in the cube completely. A gas-filled lamp run off the mains at a constant voltage was enclosed in a box through a hole in which the lamp illuminated the test-patch. In front of this hole combinations of Wratten colour filters were placed. Details of these filters are given in Table 1. Considerably narrower bands of wave-lengths could have been obtained by the use of a spectroscope, but it was felt that filters were sufficiently accurate for this type of comparison experiment.

TABLE I.

Details of the colours used in the investigation.

Combination of Wratten filters	Resultant colour of filter	Wave-lengths transmitted in $\mu\mu$	Brightness of test-patch in equivalent foot-candles
25 and 34	RED	End of spectrum to 637	0·2
25 and 56	ORANGE	700 to 680 635 to 584	0·5
22 and 57	YELLOW	632 to 552	1·0
15 and 45	GREEN	542 to 514	0·18
4 and 45A	BLUE-GREEN	530 to 473	0·2
34 and 45	BLUE	492 to 442	0·03
36 and 47	VIOLET	480 to end of spectrum	0·003

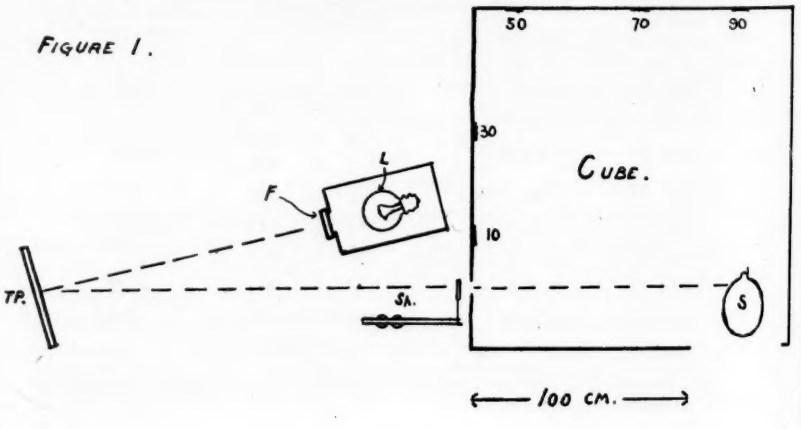
The brightness of the test-patch was determined by the critical frequency of flicker method.

A shutter of white paper was mounted immediately outside the cube. It was activated by a rotating contact allowing observation of the test-patch for 1·2 seconds. When closed the walls of the cube and the aperture had the same apparent brightness. The object of this device was to keep the subject's eye at the same level of adaptation, since a continuous light from the test-patch could in itself interfere with this level.

Method

After the subject had been five minutes in the dark the light in the cube was switched on, the resultant brightness of the surrounds being then 0·6 equivalent foot-candles. After another five minutes in this light the subject fixated the 90 degree mark and the shutter was opened. After a short rest the subject fixated the 80 degree mark and the exposure of the test-patch was repeated. This procedure was repeated for fixation marks at 70, 60, 50, 40, 30, 20, 10 and 5 degrees and finally the subject looked straight at the test-patch. At each position he described the resultant colour sensation. After all seven colours had been investigated the light in the cube was switched off for three-quarters of an hour in order to bring about dark-adaptation. The investigation was then repeated in the dark using the same method except that a rest of two minutes was given between the exposures of the different colours. The illumination of the test-patch was exactly the same for the light- and dark-adapted series. Long intervals were left between the exposures in the dark, both to preserve the condition of dark-adaptation and also to prevent after-images. These after-images have complicated the results of several workers in the peripheral retina (Hellpach, 1900) and it is stated by Baird (1905) that they result from taking readings too quickly after one another.

FIGURE 1.



Each of our five subjects repeated the experiment at least twice and usually five times. The subjects had normal vision except for trifling refractive errors.

Results

In experiments dealing with the description of subjective sensations the presentation of results is a difficult problem. At 40 degrees on the peripheral retina, for instance, the subject may on successive days describe the yellow filter as " greenish yellow," " yellowish green," " yellow but greener," " deep yellow," and so on. The remedy lies either in giving the results of all experiments verbatim or in setting down the results of all experiments side by side and then interpreting the answers on some fixed basis, averaging where necessary. The latter plan has been adopted in Fig. 2. The meaning of the symbols used can best be

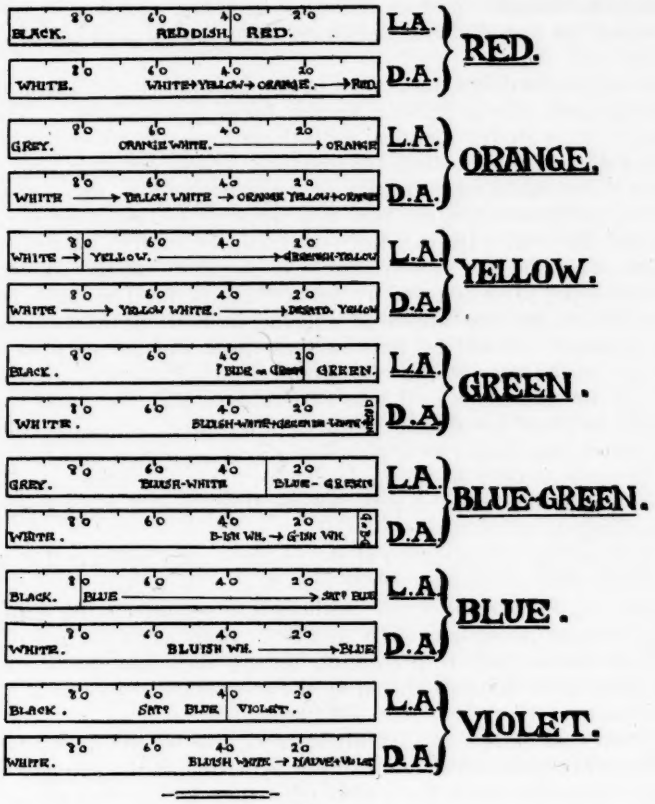


Fig. 2.

appreciated by the aid of an example. In dark-adaptation blue-green is seen by the extreme peripheral retina as white. The test-patch takes on a bluish hue at about 40 degrees, the actual reading varying from day to day and amongst different subjects. From there on the patch appears progressively greener up to the point where the eye is looking straight at the patch, when it is described as either green or blue-green.

There is a marked difference between the hue changes in passing from the periphery to the fovea according to whether the eye is light- or dark-adapted. In the light it is usually possible to give an approximate value to the position where the test-patch first appears in its true hue, the subsequent changes being small. This cannot be done for the dark-adapted eye and this phenomenon is almost certainly connected with the change over from day to night vision. The sensation from a coloured stimulus under these conditions is made up of an intense achromatic response to which is added the feeble colour sensation from the mechanism of day vision.

When the readings were taken in the dark the changes in hue in passing from the periphery to the fovea were slower. These changes were almost identical with those found by other workers. In the dark-adapted series, for instance, yellow becomes progressively more saturated. Orange first appears yellow, then orange-yellow and then orange. Red first appears yellow, then orange and finally red. In the light-adapted series the intermediate yellow stage did not appear, but it is possible that the transition was too rapid to be detected by the method used. The blue-green, blue and violet first appeared as blue in both light- and dark-adaptation. It will be noticed that there was no decided hue change in the case of the blue and yellow although there was a change in saturation. These two colours had the same wave-length as Hess' invariable colours. The third invariable colour, the green, was found to appear sometimes as blue and sometimes as green especially in dark-adaptation. It is possible that if its wave-length had been a little longer there would have been no hue change.

A superficial examination of the results would indicate that with the same filter, the colour of the test-patch is less easily recognized in the dark than in the light. Although this is interesting empirically, it is not possible to draw any deductions as to the fate of the mechanism for colour perception during dark-adaptation owing to the complication introduced by the achromatic response of night vision.

Green was extremely difficult to recognize by the dark-adapted peripheral retina and in some of our experiments the subjects were quite unable to name the colour until they looked straight at the

test-patch. This phenomenon has also been described by Gotch (1912). "In my own case such colour recognition may not occur with the Board of Trade green light until this is focussed on the retina within $1\frac{1}{2}$ to 2 degrees from the centre when the dazzle disappears and the colour becomes quite plain."

At the fovea centralis the phenomena of night vision are absent and this is associated with the absence of rods at that point on the retina. Turning, therefore, to the foveal colour sensations, we find that there are some differences between light- and dark-adaptation. The most striking result is the difficulty experienced by the observers in the recognition of blue-green when dark-adapted. In ten out of the twenty experiments this colour was called green on looking straight at the patch. The filters were made by me, and I was well aware of the difficulty found by the other observers in recognizing the blue-green and yet, knowing this, I also made mistakes with this colour. No difficulty was experienced in the light-adapted eye and green was never called blue-green. There were also some differences in the description of the yellow filter on direct fixation. It was usually called greenish-yellow in the light- and pale yellow in the dark-adapted eye.

It is surprising that in view of the amount of work which has been done on colour matching there appears to be practically none on the hue discrimination of the eye under different conditions of adaptation. Dreher (1911) working on the peripheral retina, appears to have found that a wider section of the spectrum is called yellow by the dark-adapted than by the light-adapted retina. From Baird's (1905) results it is obvious that his subjects got confused in the recognition of certain colours by the near peripheral retina. Thus at 10 degrees his green was often called yellow-green; his violet, blue; and his purple, purple-red. It is a pity that these workers did not extend their observations to the fovea. Basevi (1890) has claimed, however, that the fields of vision for colours are increased by dark-adaptation, but it is obvious that in his experiments dark-adaptation was very incomplete, in fact he says that they did not succeed if the darkness was too complete.

This colour confusion could be explained by assuming that the mechanism for colour perception (cones) becomes less sensitive during dark-adaptation and evidence from the critical frequency of flicker supports this view. Two other factors must, however, be taken into consideration. One of these is that the rods become very sensitive during dark-adaptation and the hue discrimination of the cones becomes difficult in the presence of the intense achromatic rod response. One would not expect this to affect the fovea unless the observers had been of the type described by

Abney and Watson (1916) as having relics of night-vision at the fovea, a condition for which no evidence was found. The other factor is the complication introduced by the presence of coloured pigments within the eye, namely, macular pigmentation and haemoglobin. Brücke (1851) has shown that light entering the eye through the sclera is sufficient to adapt the retina to red. In the light-adapted series, therefore, one might have been dealing with a red-adapted retina in which case the colour sensations in the dark would have been slightly different; orange and yellow would have appeared redder; green, yellower; blue-green, less saturated; blue, violet and purple, redder. There is a certain amount of evidence that changes in this direction do occur. Baird (1905) found that green was often called yellow-green and we found that a filter which appeared yellow-green in the light appeared yellow in the dark. Fick (1888) found that yellow appeared redder in dark adaptation and that the phenomenon was more marked in the peripheral retina. Dreher (1911) also found that yellow appeared redder in the periphery than at the fovea, a fact suggesting that the phenomenon may be connected with the blood vessels at the site of the retinal image in which case there would be no change of hue at the fovea since there are no blood vessels there. On the other hand some of the colour changes described in the literature cannot be accounted for by the presence of haemoglobin. Baird found that violet was often called blue by the dark-adapted peripheral retina whilst Peters (1904) found that green was sometimes called blue in the dark especially after a long period of dark-adaptation. In our experiments blue-green was often called green even at the fovea, but green was never called blue-green. This cannot be explained by the presence of haemoglobin since blue-green is only desaturated by the addition of light of the colour of haemoglobin. Whatever the true explanation the fact remains that colours are liable to be incorrectly named when the subject is dark-adapted. In the case of blue and green the colour appears very desaturated when viewed at angles greater than 5 degrees and it is not possible to guess the colour of the test-patch. These phenomena are not generally recognized. From the point of view of those occupations where the recognition of coloured lights is important it would be desirable to have further information on the effect of dark-adaptation on the perception of small feebly illuminated coloured light sources.

Of the five subjects used in these experiments four gave results which agreed very well one with another, and these subjects also gave the same results in the experiments on the critical frequency of flicker. From evidence which has been published elsewhere (Lythgoe and Tansley, 1929 *b*), we concluded that the fifth subject was probably partially night-blind. The condition might have

been due to deficient powers of dark-adaptation or else to a greater proportion of cones to rods than is normal in the peripheral retina. The peripheral colour sensations of this subject were qualitatively the same as those of the other subjects and there was the characteristic desaturation of colours in dark-adaptation indicating that the condition was present in a mild form. For red, orange and yellow, however, this subject's colour fields in light-adaptation were slightly larger than those of the other subjects, and the conclusion seems to be that her peripheral retina was well supplied with the colour perceiving mechanism. Unfortunately, however, the differences from the normal were only slight and it is not possible to draw any definite conclusions.

Summary

(1) Experiments were made with a view to determining the influence of the adaptation of the eye on hue discrimination in the central and peripheral parts of the retina.

(2) During dark-adaptation colour sensations are much desaturated and also hue discrimination is less acute.

(3) The possible causes of this diminished acuteness of hue discrimination are discussed. It is due either to: (*a*) the suppression of the mechanism of colour perception during dark-adaptation; (*b*) swamping of the sensation by an achromatic rod response; or (*c*) the presence of pigments within the eye. The results do not point unequivocably to any one of these causes.

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AN INVESTIGATION OF MINERS' NYSTAGMUS

BY

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As an ophthalmic and aural surgeon practising in a colliery area, I meet many cases of miners' nystagmus in miners' hospitals, and many cases are referred to me by colliery companies and the South Wales Miners' Federation.

I feel I have some advantage over some previous investigators, I am both an ophthalmic and an aural surgeon; I have not read any literature which states that the inner ear has previously been investigated in connection with this disease.

The following table shows how nystagmus has increased since 1910, and the economic drain it is upon the country

Year	Per cent. incidence of fresh cases	No. of fresh cases	Total No. of cases	Cost of nystagmus compensation	No. of men underground
1910	0·11	956	1,618	£37,800	834,000
1929	0·34	2,577	9,838	£440,100	762,300

When considering the economic loss to the country, one must remember that not only is £440,100 spent on compensation but that in addition 10,000 men are unemployed as a result of the disease.

This table shows that although the numbers of underground workers have diminished yet the incidence of the disease has increased threefold.

"*Observations on Miners' Nystagmus and Environment.*"—A committee appointed by the Medical Research Council investigated the disease and issued a report in 1922, and a second report in 1923; many of the improvements therein suggested have since been carried out in many collieries, yet the incidence is very high.

During the past four years, I have investigated in detail 212 cases, the average period of examination per case, being about half an hour. My investigations have taken place in my consulting-room, in a dark room at the pit head, and underground.

Occupation Analysis in a Series of 212 Cases.

Colliers	141
Hauliers	21
Timbermen	17
Repairers	14
Labourers	5
Officials	3
Colliers' Helpers	3
Others	8

Colliers head the list; the frequency of the disease amongst hauliers, timbermen and repairers is slight in comparison. Many of the non-collier grades have worked as colliers at some period, which would partly account for the high incidence amongst non-hewers.

Types of the Disease.—I have classified the disease into four types:—

(1) Latent.
(2) Sub-acute.
(3) Acute.
(4) Neurasthenic stage.

Latent.—I have investigated these various types; the symptoms and signs vary numerically and in intensity in these categories.

In the latent variety, as a rule the patient does not know that he has the disease. He complains of slight photophobia, oscillations may or may not be present, he is worse some days than on others; as a rule on his " bad days " oscillations are present, particularly at the end of the shift, also headache; he rarely reads at night on account of eye strain; the lights of his fellow workers are a source of annoyance, particularly underground when he is going to his work and returning to the cage; his vision is bad and he is often giddy in twilight and at night; and he takes a longer period to " get his sight " underground.

In many latent cases I could find no signs of nystagmus before the shift; but after the shift oscillations could be provoked after strenuous bending upwards and downwards. Oscillations were temporary and were usually only present whilst the patient was giddy. In some cases other signs such as photophobia and some difficulty in fixing the letters of a reading chart were present.

These latent cases invariably continued their occupations, unless a diagnosis of nystagmus was made by their panel doctor who informed the patient. This is a fatal error on the part of the practitioner; the man becomes introspective, and, as a result, his

subjective symptoms multiply, he becomes hypochondriacal and probably he will eventually conclude that he must have a rest if he is to be cured. He obtains weekly compensation for a time, and, when he resumes work, his output is below the average, and he is sparing himself lest he should get worse.

The collier's doctor must remember that 25 per cent. of colliers have nystagmus, and he is doing his patient an injustice if he informs him of the presence of latent nystagmus, unless he is of opinion that he is incapacitated; because if the man is introspective it is only a matter of time until his brooding may result in incapacity.

I have seen several cases of latent nystagmus over a period of years; many have got no worse.

Sub-acute Type.—In this type the patient may complain of several of the following symptoms:—headache, frontal or occipital; dazzling of lights after working in an awkward position; particularly towards the end of the shift, he may notice neighbouring lamps irritating and "going around;" giddiness; he does not see the coal face so well; his sight is bad in twilight; and he feels giddy for a few hours after work.

On examination the signs of the disease vary. In three cases before the shift, there was no sign of the disease; but in most cases signs of the disease were present.

The commonest signs found were oscillations, photophobia, giddiness on bending, difficulty in fixing and reading the 6/18 of a Snellen's chart at six metres whereas before the shift he could read 6/9 without much difficulty.

It is very typical of nystagmus that the men pick out the letters of a reading chart slowly, each letter has to be fixed separately. There may be no other signs of the disease, on the other hand they may have some of the other signs which are usually present in the acute type.

As a rule the sub-acute case is able to continue his underground work; in many cases he realizes that he has nystagmus, but he continues working, because he can earn a better wage than if he were on compensation. He may suffer acutely particularly towards the end of the shift. On the contrary, some say that their symptoms are worse at the beginning of the shift and they diminish later when they "get their sight" (when dark adapted); the numbers are few.

Acute Type.—In this stage all or some of the previously mentioned signs are present, but more marked. Most observers will agree with me when I state that no two cases of acute nystagmus are alike.

In most cases the following symptoms and signs are present to

a greater or lesser degree, some signs being prominent in one case and absent in another.

As a rule they walk with head slightly bent backwards, cap pulled down over forehead, and upper lids lowered; this attitude is to avoid light and annoyance of moving objects. The gait is slow with the legs slightly wide apart. In the twilight it is common to see them walk unsteadily and knock against stationary objects; at night when motor car lights approach them on the road, they stand or sometimes lean against the wall and look away until the lights have passed, because giddiness, temporary blindness, photophobia and headache are provoked; some never come out at night unless they are led by a friend.

Several bad cases could not bend even to lace their boots as it provoked marked giddiness, headache, pains in the eyes, and movements of surrounding objects; the symptom causing the greatest discomfort being giddiness.

In some cases noises provoked the symptoms already mentioned as also did mental excitement of any kind. Many stated that they could do some work on the surface if they were permitted to work at " their own pace."

Signs on Examination.—Photophobia is present, particularly on exposure to artificial focal illumination. This sign is usually associated with lid spasm or spasm of the elevator muscles or both.

Oscillations of the eyeballs are nearly always present—although in some cases they are only provoked on bending, slow oscillations at the rate of 100 per minute being most obvious to the naked eye. If the oscillations be fast and fine with a frequency of 200 to 350 per minute, they may be invisible to the naked eye, but, if the retinal vessels be focussed with an ophthalmoscope, they cannot be missed by the most inexperienced observer.

In most of the literature they are referred to as being of a rotatory type. I consider this is a misnomer as an oscillation is not a complete rotation. I prefer to describe the to and fro oscillations as being pendulum-like. They describe a little more than a semi-circle; occasionally oscillations are horizontal or oblique.

Oscillations may not be very marked, but it may be taken as a general rule that, if the patient bends up and down rapidly until giddiness is provoked, the oscillations will increase in frequency and amplitude.

Bending also provokes or increases head and hand tremor, spasm of the lids and elevator muscles.

When giddiness is present the pulse rate increases in frequency and it is occasionally irregular, even when disease of the heart is not present.

The signs and symptoms of the disease are more marked on some days than on others. I have many cases on record where patients have only had sub-acute signs of the disease on one day and on the following day marked acute signs. The patient usually stated that on the day his " nerves " were bad his nystagmus was worse.

Neurasthenic Stage.—In this stage the patient in addition to having signs of the disease has various neurasthenic symptoms. This is the type of case which may remain on compensation for ever. If he had been given suitable surface work, he would possibly have never become a neurasthenic; he would gradually have regained his self-confidence.

Significance of Oscillations.—Some men may have very fast and marked oscillations, yet they never have a sensation of objects around them moving; others with a similar type of oscillations or even with oscillations of a slower rate state that all objects around them are "on the move." In particular they complain of the lamps of their fellow workers which they may state are going around " like a ball of fire."

I have noticed that the men who complain of objects moving have always got marked vertigo.

I am of opinion that one cannot decide the extent of incapacity by the frequency or amplitude of the oscillations. I have known patients who have had slow oscillations which might even be described as nystagmoid jerkings who were absolutely incapacitated. On the contrary I have known other patients whose oscillations were fine and fast who suffered no discomfort.

I have concluded that the most incapacitating symptom and one which accounts for 80 per cent. of all incapacitated cases is vertigo (giddiness). If vertigo did not occur in this syndrome I am convinced that there would be little or no incapacity. I consider that vertigo is the major symptom and that most other signs and symptoms are secondary to the same cause which brings about vertigo. This I will discuss later in my paper.

Incidence of Nystagmus.—In Tables No. 1 and No. 2 are the official figures supplied by the Mines Department for the years 1908 to 1929; these figures include only the cases who *have* received compensation for the disease in the United Kingdom which was roughly, in 1929, 1·2 per cent. of underground workers employed.

In the underground workers whom I have examined the incidence of the disease was 23 per cent.; the incidence is even higher at the end of a shift; most cases are of the latent and sub-acute types.

The average percentage of fresh cases in underground workers who received compensation from 1909 to 1920 was 0·22, from 1921 to 1929 was 0·32.

TABLE I.

Showing percentage incidence and number of cases receiving compensation for the first time during the year, total number of cases receiving compensation during the year, cost of all industrial diseases, number of men employed underground, number of cases disabled in the mining industry, and output per underground worker per year in tons.

Year	Nystagmus			Cost of all industrial diseases	No. of men employed underground	Accidents (1,000s)	Output. Tons per man per year
	Fresh Cases		Total No. of cases				
	Percentage incidence	Number					
				£*			
1908	0·05	386	460	13,000	783,000	137	334
1909	0·08	631	1,011	26,000	805,000	154	328
1910	0·11	956	1,618	42,000	834,000	166	317
1911	0·16	1,375	2,519	68,000	849,000	167	320
1912	0·16	1,376	3,195	85,000	865,000	167	301
1913	0·25	2,402	4,551	113,000	895.000	195	321
1914	0·28	2,409	5,993	164,000	835,000	179	318
1915	0·24	1,780			743,000	not available	341
1916	0·20	1,626	not available		782,000		328
1917	0·18	1,461			799,000		311
1918	0·24	1,917			783,000		291
1919	0·29	2,718	6,449	225,000	933,000	134	246
1920	0·29	2,865	7,028	343,000	978,000	134	235

* Home Office returns do not separate cost of nystagmus from other industrial diseases. Nystagmus is responsible for over 90 per cent. of this cost.

It must be noted that from 1909 to 1919 the eight hour shift was in operation, whereas from 1919 to 1926 the seven hour shift existed; yet the incidence of the disease increased in the latter period.

There was a reversion to the eight hour shift in 1926, yet the average incidence of the disease was less from 1927 to 1929 as compared with the years 1923 to 1925.

It is difficult to draw any conclusions from these figures; although the nystagmus incidence varied little, yet the output increased. This increase in output can be accounted for by:—

The men have worked better since 1926; half an hour longer shift; and increase in the use of machinery underground.

My own opinion is that, during the period 1926 to 1929, many men have continued to work although they have suffered acutely from nystagmus. Many of these men told me that they feared to claim compensation lest they would not be employed again when they were fit, as there were so many fit men available, who had not contracted the disease.

Some observers in the past have stated that when wages are low, the numbers on compensation are high and when wages are high the numbers on compensation are low; the following figures favour this statement. In 1920 the percentage incidence of fresh cases was 0·29 when wages were very high, in 1928 and 1929 when wages were very low the percentage incidence was much higher, 0·34.

I have made enquiries from colliery managers as to the type of workman who is at present receiving compensation. Out of 76 cases, 40 were considered good workmen, 29 fairly good, and 7 lazy and incompetent. A good workman is not the type who seeks compensation if he can avoid it.

TABLE II.

Number of nystagmus cases for which compensation was paid for the first time during each of the years 1921 to 1929 and the number of cases per 100 men employed underground. Total number of nystagmus cases for which compensation was paid during each year. Cost of compensation for all industrial diseases affecting miners. Number of (accident) disablement cases at all mines. Average number of men employed underground at coal mines and average annual output of coal per underground worker.

Year	Nystagmus			Cost of compensation paid for all industrial diseases affecting miners *	(Accident) Disablement cases at all mines†	Average No. of wage-earners employed underground at coal mines	Annual average output of coal per underground worker
	Fresh Cases						
	Number	Per 100 men employed underground	Total No. of cases				
				£			Tons
1921‡	1,913	0·21	6,717	396,000	103,784	908,100	180
1922	4,092	0·44	9,155	587,000	201,370	921,700	271
1923	3,872	0·40	11,142	595,000	245,479	966,100	286
1924	3,271	0·34	10,906	675,000	214,171	966,200	276
1925	3,444	0·39	11,334	610,000	197,388	878,200	277
1926‡	1,771	‖	10,041	542,000	117,252	‖	‖
1927	1,801	0·22	9,734	489,000	188,978	814,100	309
1928	2,554	0·34	9,818	503,000	185,823	745,000	319
1929§	2,577	0·34	9,838	489,000	196,515	762,300	338

* Home Office returns do not separate the cost of nystagmus from that of other industrial diseases affecting miners.

† Including cases affecting surface and underground workers and cases where there was payment for compensation.

‡ The years 1921 to 1926 were affected by prolonged disputes in the coal mining industry.

§ Provisional figures.

‖ Cannot be stated.

Association of Incidence and Age.—I have seen three cases of nystagmus in colliers' helpers, they were boys of poor physique and neurotic of temperament. One boy informed me that his father had suffered from the disease.

It is impossible to associate nystagmus with any particular age, because a man may have had nystagmus for years before it has become sufficiently bad to claim compensation. I have had no case of a haulier, timberman or repairer affected before 39 years of age.

In one particular pit where the percentage of hauliers affected was high I noted that the lighting of the roadway was particularly bad; but the ventilation was considered good.

In the same pit I was informed that there was a portion of a seam where the incidence of the disease was much higher than in other portions of the seam. The width of this portion of seam was four feet, the temperature was higher than in other portions of the seam and the ventilation was poor, the composition of the coal was similar to the rest of the seam.

Illumination.—Most observers have concluded that the principal cause of nystagmus is defective illumination, and they forecast that when illumination is improved, the disease will cease nearly entirely.

The facts so far are not in agreement with their observations, as, since the introduction of electric lamps, the disease has increased considerably. However, as you will note later on in my paper, I consider that the principal cause of the disease is defective illumination.

For one electric lamp used in the United Kingdom in 1914, there are now nearly seven in use, and it is reckoned that every other underground worker has an electric lamp.

In most of the pits which I have investigated the great majority of the workers use 2-volt electric lamps. The majority of these lamps give a mean spherical C. P. of 0·96 when new.

Effective illumination is to a great extent dependent upon efficient lampmen and good bulbs. In the past, bulbs were like mass production motor cars; some were better than others. Now since the introduction of the British Standard Specification Ref. 377/1930, bulbs are required to show a C.P. of 1·05 in the maximum direction, which would be more than ½ C.P. when looked at end-on.

The purchaser has now only to specify his bulbs to be to B.S.S., and he is sure to have the best available light as a result. The illumination with cheap untested bulbs may be 25 per cent. worse than the illumination given by standard bulbs.

In one pit I found that from 1916 to 1918, oil lamps were used nearly altogether. In the period 1927 to 1929 nearly all electric

lamps were used, yet the incidence ratio of nystagmus increased as 3 : 1 in the latter period. In one house-coal pit which employs about 300 workers, acetylene lamps only are used; there has not been a case of nystagmus for the past three years.

I am of opinion that the increase is not directly due to the introduction of the electric lamp, but to the fact that the men who have become incapacitated were men who were suffering from latent nystagmus whilst using oil lamps; when they changed over to electric lamps, the irritation of the brighter light aggravated the disease. Nevertheless, I have examined several men under 30 years of age, who have never used anything but an electric lamp, and yet they have developed the disease. An electric lamp, particularly with plain glass, is a more irritating light than an oil lamp; hence, many of the cases who sought compensation would probably have been able to continue work if they were working in a pit where oil lamps only were used.

In 1927, three colliers who were members of friendly societies, consulted me under the Ophthalmic Benefit Scheme; they required glasses for reading. In my routine examination I discovered that they were suffering from nystagmus, but they were working regularly in pits where frosted lamp glasses were used. Owing to the colliery shutting down, they were unemployed; two of them succeeded in getting work in a colliery where plain glass electric lamps were used, and within six weeks both of them were incapacitated with nystagmus.

As a result of this experience I examined batches of colliers at two pits, one in which frosted and tinted lamp glasses were used and others where the glasses were plain; the incidence of nystagmus was very similar. I considered that there were several men in the tinted glass pit, who had marked subjective and objective signs and symptoms, who if they were working in plain glass pits would have had to cease work.

Tinted and frosted glasses have little effect on the incidence of the disease, but the glare is less than with plain glass, and, as a result, men can continue work even when the signs and symptoms of the disease are marked.

The disadvantage of frosted prismatic glass is that it reduces the illumination by about 10 per cent.; on the other hand this is compensated for by the fact that there is not a noticeable pillar shadow, and the light is softer. Most miners' lamps have four or five steel protection pillars; with plain glass lamps marked shadows of the pillars are present.

The ideal tint is green; it cuts out actinic rays which are the most irritating. The amount of green tint required to diminish harmful glare is less than that required with other colours; consequently the diminution in illumination is less.

Errors of Refraction.—In 76 cases, many of which were contested in the County Court, I carefully studied the association of errors of refraction and the incidence of the disease. I find no association between refractive errors and the incidence and severity of the disease. In many cases the men with the least error of refraction were those with the worst subjective symptoms. I find that the age of incidence is somewhat above the average in myopic people. I suggest that this is because their visual acuity is so poor that diminished illumination and glare takes longer to affect them than other workers; and as their far point is near, they accommodate very little.

I noticed that, when vertigo was most marked after bending, the high myopic case could fix objects with greater ease than men with comparatively little error of refraction. This was due to the fact that spasm of the elevator muscles was less marked, which may be accounted for by the high myopic eye being much longer in the antero-posterior diameter; it is a bigger eye than the normal eye; consequently the elevator muscles have less effect in rotating the eye upwards and so diminishing fixation power. Also in the high myopic eye there are usually several areas of choroidal atrophy, and the amount of light stimulation of the retina is less; consequently there is less retinal irritation.

Association of Accident with Nystagmus.—In three cases, accidents at work were the alleged cause of nystagmus. In one case a fall of coal injured the head causing a frontal scalp wound; in the second a fractured forearm occurred; in the third case the man was buried under a fall of coal, and he sustained considerable shock.

I had not seen these cases before their accidents, so I cannot say if they were suffering from the disease or not.

I concluded after interrogating them that they were suffering from latent nystagmus, and that the shock of the accident to their central nervous system provoked acute nystagmus. One man is still on compensation after three years, and, although oscillations, vertigo, lid spasm and head tremors are present, he has in addition general neurasthenic symptoms.

Association of an Acute Illness.—In three cases men had no difficulty in performing their work underground until they developed an acute illness. Two developed influenza; one was an ordinary mild attack; he was in bed for five days; two days after resuming work he had giddy attacks and the lights underground were " all on the move," he was incapacitated with nystagmus for several weeks.

The second case of influenza developed meningeal symptoms, and he did not return to work for one month. Soon afterwards

he developed nystagmus and he was on compensation for six months.

The third case contracted pneumonia and whilst convalescing he had to be supported owing to vertigo when walking, and could not walk on the road at night as motor car lights provoked giddiness. He was certified suffering from nystagmus, and was on compensation six months.

As in the case of accidents, I have little doubt that the men had latent nystagmus which became acute as a result of an acute illness.

Interrogation of Nystagmus Cases.—I have interrogated several nystagmus cases whom managers considered were good workmen before they were incapacitated, and who did not cease work until they were very acute cases.

My questionnaire led me to the following conclusions:—

(1) The symptom which provoked the greatest discomfort was giddiness.

(2) Other men's lamps caused them most annoyance going to and returning from work underground.

(3) A man's own lamp rarely caused him any discomfort. One man's expression was very explanatory " I never look at my lamp. I always pick my lamp by looking at it out of the corner of my eye." In other words, when handling his lamp he always used peripheral vision.

(4) Most men said that they moved their lamps as little as possible, as when turning to move them they got the glare of other men's lamps; which provoked discomfort. Another reason for not moving their lamps was, that the change in illumination of the coal face was often a source of annoyance.

(5) If the lamp was too near the portion of coal face on which a man was working, the swaying motion of his head brought the lamp into his field of vision momentarily, and the glare was irritating. As a result, in many cases the men were having even worse illumination than was available; as they were loath to move their lamps owing to the glare and discomfort provoked.

Amount of Illumination.—If coal were a good reflecting surface the underground illumination would be comparatively good; but it is an unusually bad one. The absorption of light is very pronounced; it varies with the composition of the coal; but from 70 to 90 per cent. of all incident light is absorbed by the coal. It is the reflected light on which the worker depends; so if his lamp is 1 C.P. at the beginning of the shift, only 10 per cent. to 30 per cent. of 1 C. P. is available. It may be definitely less than this when one considers that:

(1) The angle of incidence is equal to the angle of reflection

and as the coal face is not a smooth surface, there is very much scatter of reflected rays and consequently only a small proportion of reflected rays is available for the worker.

(2) The intensity of the illumination has a constant ratio to the distance of the light from the coal face, one candle at one foot from the face gives as much illumination as nine candles at three feet from the face.

As a result of these various conditions and others of less importance, the worker, depending upon the distance of his lamp from the coal face, may be only receiving reflected light to the extent of 1/500th to 1/1000th of a candle power to perform his work.

Comparison of Lamps.—The one candle power lamp rarely produces 1 C. P.; it is more often 0·75 to 0·90. Further, its end-on illumination may only be 0·50 C. P.

There are still further reductions in illumination. In plain glass lamps the pillars throw a shadow—these shadows are nearly devoid of illumination and the size of the shadow on the coal face is dependent on its distance from the lamp. The vertical illumination is very slight owing to the small size of the bulb, and the head plate, which is, as a rule, about 3½ inches in width.

It is admitted by all investigators that the present illumination with the 1 C. P. lamp is totally inadequate; slight improvements can be made such as paraboloid reflectors, etc.; but the glare as a result of the improvement is greater.

Alternatives to the 1 C. P. lamp are the cap lamp and the 4 candle power alkali lamp.

The cap lamp is the ideal form of illumination; it has the following advantages: it develops as much as 6 C. P.; the worker directs the light on the portion of coal face on which he is working; his lamp is never an annoyance to him from a glare point of view, as he cannot see it; glare does not occur going to and coming from work, if other men carry their lamps as directed; and the same amount of dark adaptation is not required as the man uses macular and perimacular vision.

The objections to it are:—Until a man becomes accustomed to wearing a cap lamp, it is uncomfortable and often causes headache as a result; he has to alter its position on his head and it is continually shifting and the men object to the weight of the accumulator around their waists; the accumulator is often in the way when the position of the body is altered; these annoyances are worse in narrow seams.

Electrical engineers would have no difficulty in producing a head or hand lamp of any candle power or voltage which the collieries would require, but the higher the voltage, the greater the weight of lamp. It is not practical to have a heavy lamp.

A *via media* between the present hand lamp and the cap lamp, is the 4 candle power alkali lamp.

I feel confident as a result of my investigations underground, and in my dark room on the surface, with the 4 C. P. Concordia alkaline lamp, that its lighting is sufficient to insure the worker using macular and perimacular vision which, in my opinion, is necessary if nystagmus is to be avoided.

Description: It is much bigger than the 1 C. P. electric lamp, it is fitted with prismatic frosted glass, the glass area is about four times more than the area of the 1 C. P. lamp, the case is of cadmium plated steel containing two complete alkaline cells, the combined voltage of which is 2·6 volts. These cells are manufactured on a new principle developed by Edison. The positive plate is built up of reinforced steel tubes which are filled with active material. These tubes are immensely strong, and can resist the swelling which has so often been the cause of failure with alkaline lamps in the past. Its weight is roughly 9½ pounds, the capacity 18 amp-hours, the bulb, which has a " kinked " filament, consumes 1—6 ampéres. The light is equal to four Haffner candles. (One Haffner candle power is equal to 0·88 of one English candle power). What are the objections to this lamp? The only possible one is its weight. After all the man who should object to its weight is the collier; I have interrogated men who have carried and worked with my experimental lamp, and none of them objected to the weight, they said the better light compensated them for the increase in weight. In fact, in one district a batch of miners have agreed to give the lamp a trial, and the company are installing several dozen lamps.

The following are the advantages which I have noted with this lamp:—

(1) The glass is frosted and prismatic. As a result of prismatic glass, to the naked eye there are no pillar shadows; in reality there is a slight reduction of light in the pillar area.

(2) As a result of frosting and prisms there is obliquity and diffusion of rays; the glare as a result is not more than that with a 1 C. P. plain glass electric lamp.

(3) There is good illumination on the coal seam even as high as 12 feet as a result of much larger glass area; higher C. P.; bigger bulb and longer kinked filament; and a head plate 1/5th less than the head plate of the average 1 C. P. lamp, giving more vertical illumination.

(4) As a result of good illumination the collier has not to move his lamp as much as he would have to in the case of the 1 C. P. lamp.

(5) The eye becomes dark adapted more quickly because partial dark adaptation only is necessary.

After 8½ hours there is only a reduction of 0·25 C. P.; in the case of the 1 C. P. lamp the illumination after the same period is

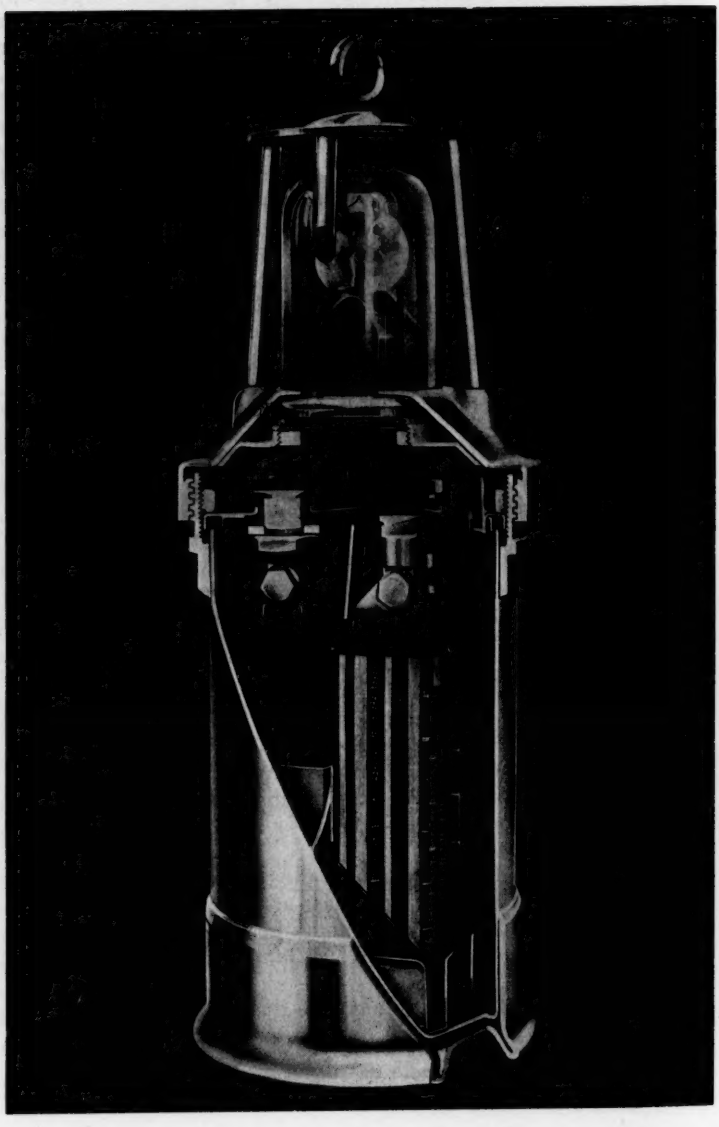


FIG. C.

Alkali Lamp in Section.

about 0·5 C. P. In the former case there is only a small fractional reduction in illumination; in the latter the illumination has been reduced by nearly half.

Effects of After Images on Accuracy of Aim.—In conjunction with a colleague I have performed the following experiments in my dark room with:—Flame lamp; 1 C. P. plain glass electric lamp, and 4 C. P. frosted electric lamp.

The procedure was somewhat similar to that of Dr. Vernon and Mr. Adams.

(*a*) On a black velvet curtain background three feet square, and three feet from the ground were placed 20 squares of paper 4 mm. square at a distance of 1½ inches from each other. I sat on a stool at arm's length from the curtain and after 15 minutes dark adaptation

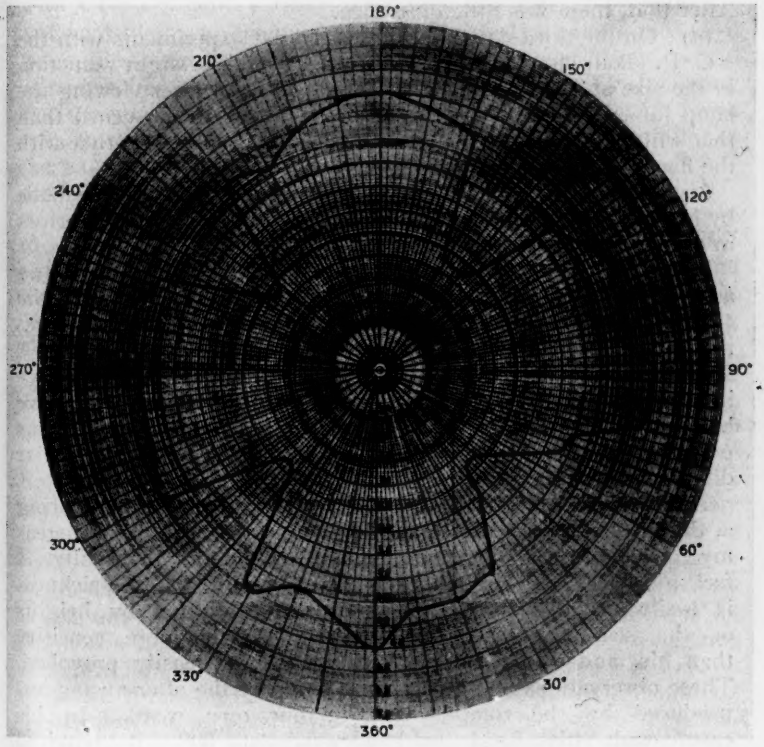


FIG. D.

Light-curve of Alkali Lamp with Prismatic Glass over 360 degrees.

the 1 C. P. lamp was suspended just higher than the curtain and midway between the curtain and myself; I then placed my hand holding a pen next my chest, and at one second intervals proceeded to prick each piece of paper. The error in accuracy of aim was measured by my colleague. This experiment was merely a control.

(*b*) After a reasonable rest I stared at the 1 C. P. plain glass lamp for two seconds and then proceeded with pricking test as in (*a*). In the first four pricks, considerable error in accuracy of aim was made; as I proceeded the error diminished, and after ten attempts the errors were equal to those found in control test (*a*).

(*c*) On the following day as I was perhaps becoming accustomed to the targets—I reduced their size to 3 mm., and performed similar experiments to (*a*) and (*b*) with a flame lamp. The amount of error in experiment (*b*) was 20 per cent. less for the first five pricks as compared with the plain glass electric lamp. After that, there was little difference.

(*d*) On the third day I performed similar experiments with the 4 C. P. alkali lamp with frosted glass. I made a slight reduction in the size of the targets. The amount of error after viewing the lamp for two seconds was slightly less (about 15 per cent.) than that with the plain glass electric; but it was more than that with the flame lamp looked at broadside.

My colleague performed similar experiments, and the error made by him was 50 per cent. less than mine, but our proportion of errors in each experiment was very similar.

These experiments show that the effect of after images on accuracy of aim varies in different individuals; and that the 4 C. P. frosted prismatic lamp produces less intense after images than a 1 C. P. plain glass lamp.

I was very surprised that there should be such a big difference in accuracy of aim between my colleague and myself—we have both excellent vision, about 6/6 in both eyes. In the experiments performed by Dr. Vernon and Mr. Adams, there was also a similar difference between the two observers, but it was not so marked.

After interrogation and introspection, we discovered that staring at the bright light provoked slight giddiness in my case, whereas my colleague did not complain of giddiness. Normally, I feel giddiness on heights, and on a rough sea sea-sickness is easily provoked; my colleague is not affected by heights or the sea. Evidently my internal ear is more sensitive than his, and consequently giddiness is more easily provoked. These observations stimulated us to compare the after-nystagmus produced by the rotation test in our own cases. In his case, with his head held forward at 30°, it required 18 complete revolutions on a suitable chair, to provoke labyrinthine after-nystagmus which lasted eight seconds; vertigo

only continued for a few seconds. In my case eight revolutions produced after-nystagmus which lasted 17 seconds; vertigo continued after the nystagmus ceased. I have no doubt that the giddiness which I experienced after staring at the lamps was vestibular in origin, and that part of my error in accuracy of aim had a similar origin.

I have since performed experiments similar to (*a*), (*b*), (*c*) and (*d*) with three colliers who are suffering with nystagmus but are doing surface work. The errors in accuracy of aim which they made, were much greater even than mine.

The conclusions I have come to are, that the irritation provoked by after images with a 4 C. P. prismatic frosted glass lamp are less than those provoked by a 1 C. P. plain glass electric lamp even in men suffering with mild nystagmus, and that the accuracy of aim with a 4 C. P. lamp is better because of the better illumination.

Two colliers who had recently been certified as having recovered from the disease, and had returned to underground work, were supplied with the 4 C. P. lamp for one shift. The following was the procedure, and the results. For the sake of clarity, I will refer to the men as " A " and " B "; both men were working in the same district, walking to their work underground. " A " carried the lamp half the way, he was followed by " B "; " B " stated that the 4 C. P. lamp did not irritate his eyes any more than the other lamps in front of him. On the other hand, when " B " took the lamp and preceded " A " the latter stated that he found the glare slightly more irritating than that of the other lamps. Normal men who followed the lamp, did not notice anything abnormal.

" B " worked the first half of the shift with the lamp and stated that the lamp was ideal, stating similar advantages to those already mentioned earlier in the paper. " A," who used the lamp in the second part of the shift said he would prefer a " duller " light, although he could see much better with this lamp. I may say, on examining these men, that " B " had recovered entirely from the disease; whereas " A," had lid spasm on exposure to light, slow oscillations and vertigo after bending.

The variation in the labyrinthine tests performed on my colleagues and myself, stimulated me to perform similar tests on colliers suffering from nystagmus. The type of nystagmus produced by rotation and syringing tests in normal people, is different from the pendulum type of oscillations in miners' nystagmus. Vestibular nystagmus consists of two components, a slow one and a quick one; the slow component is vestibular in origin; the fast component, which is a return to the original position of the eye, is cerebral in origin. Physiologically, the condition

Labyrinthine (Internal Ear) Tests:

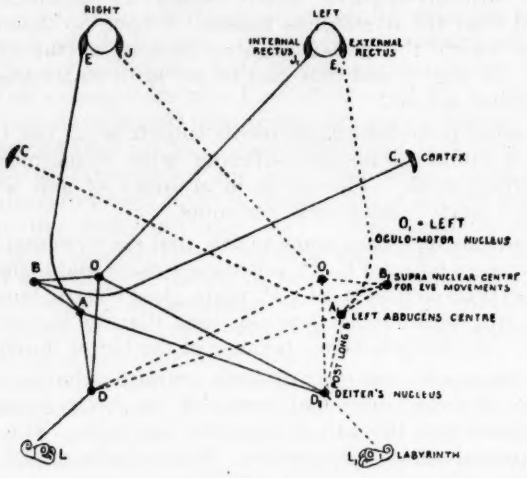


FIG. E.

Diagram showing mechanism of physiological horizontal nystagmus to the left, after rotation of a patient (upright position) to the right. The brain and eyes are looked at from below and in front. On the left of the diagram (the right side of the patient) is shown, by continuous lines, the path of the impulse from the labyrinth producing the slow vestibular component to the right. On the right side of the diagram, dotted lines indicate the path of the impulse from the cerebral cortex (C) which produces the rapid (cerebral) component to the left.

is most marked when the patient looks in the direction of the cerebral component.

I have syringed the ears of, and rotated several miners with nystagmus, who had no oscillations when at rest, but in whom oscillations could be provoked by bending.

In rotating and syringing these cases, oscillations were provoked; but they were not of the normal vestibular type, one slow and one fast component; on the contrary they were the typical oscillations of miners' nystagmus, mostly of the pendulum type. In most cases oscillations were provoked much more quickly than in normal people; in some cases on rotating them from right to left, marked oscillations were provoked, but on rotating from left to right, the oscillations were not marked. Mostly, marked vertigo, head and hand tremors, were provoked by these tests; and in one particular case the patient had to remain in my rooms for two hours, before he was fit to proceed home.

One naturally wonders why ordinary vestibular nystagmus was

not provoked in cases of miners' nystagmus after rotation, I can only hazard a theory to explain these alterations.

Starling in his physiology states, " That extirpation of one labyrinth causes partial loss of tone in the muscles of half the body and stimulation of the labyrinth causes movements of the eyes which may or may not be associated with movements of the head. The labyrinth is to a great extent in control of our posture, the resultant effect of its afferent and efferent impulses is to maintain a reflex posture of the head and eyes so that the optic axes in a position of rest are directed towards the horizon, the cerebellum is a subsidiary of the labyrinth."

I suggest that the following signs of miners' nystagmus are labyrinthine in origin:—oscillations, lid spasm, head and hand tremors, vertigo, fast pulse rate, and general inco-ordination. They are due to alteration in the afferent impulses to the labyrinth, and as a result, alteration in the efferent labyrinth stimuli with a consequent alteration in the tone of the muscles, and hence, tremor.

On ascertaining that pendular nystagmus was provoked by rotation tests in miners' nystagmus, I made further aural investigations.

I have found with rotation tests, that the labyrinths of nystagmus cases are, as a rule, more sensitive than those of normal people; and it is quite common to have the labyrinth on one side, more sensitive than on the other side.

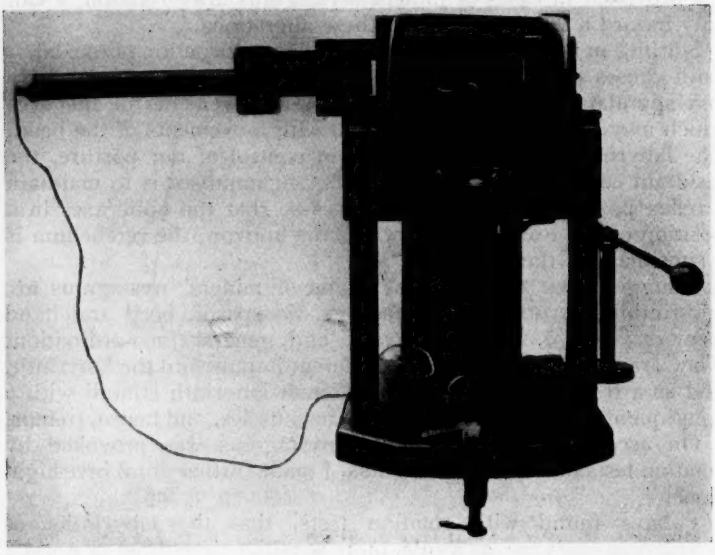
The external canals are tested with the head held forward at an angle of 30°, the posterior canal on the right side, and the superior on the left side, are tested when the patient's head is held forward and to the right, lambda approaching the right shoulder. The latter two tests I rarely performed, as the giddiness provoked often lasted for a day. I will give further consideration to these observations later.

Muscle Test.—The apparent muscular inco-ordination, the presence of oscillations, and the presence of various muscular phorias with the Maddox rod test; stimulated me to investigate these conditions more thoroughly.

For this purpose I use the myophoriograph. This instrument was designed primarily, to record and investigate, in a graphical manner the co-ordination of a pair of eyes in dynamic action.

The instrument consists of a device, in which one eye fixes a luminous target, which is viewed through a prism rotated about an axis, coincident with the line of fixation. The image of this target is mentally projected on to a black screen, which is visible only to the companion eye.

On the surface of this black screen is another target, which is free to move in all directions parallel to the screen; and is operated by a lever which is held in the hand of the patient.



THE MYOPHORIOGRAPH.

By varying the design of the two targets, different amounts of fusional stimulus can be demanded. The quality of fusion can be demonstrated in all positions of the eye, by using test objects of such a size as to occupy the macular area of both eyes.

To investigate the co-ordination of the two eyes with prism suspended, two dissimilar targets are employed, one occupying the foveal area, and the other, the paracentral zone.

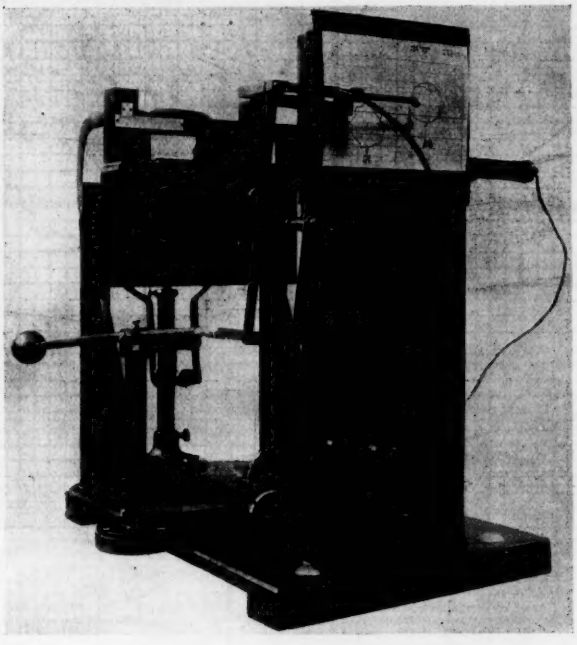
The actual measurement of the lack of co-ordination of two eyes is obtained by dividing by two the number of small squares between corresponding points of the graph; the result being the amount of error expressed in prism dioptres, the measurement being made in the direction in which the error is to be estimated, *i.e.*, horizontally in lateral errors, and up and down in the vertical errors. The average error is obtained by measurement between the geometrical centres of the figures described, and divided by the factor two, as above.

The method of operation is as follows:—The patient is seated, and his head is placed in a chin and forehead rest, so arranged as to permit no movement. The eye under observation views the luminous target through the rotating prism; the companion eye fixing the movable target on the black screen. The prism is set in rotation (at an even speed by means of a motor), and the patient is

instructed to follow and maintain fixation on the moving target, and to keep it encircled with the second (ring) target which is viewed with the second eye.

By means of a pantograph arrangement, the pattern described by the " follower " target is communicated to a pen travelling over the graph card, and its course is recorded on the latter.

In the construction of the instrument, it is arranged that in a case of orthophoric co-ordination, the figure described has for its



centre the cross lines of the graph card, and the record for the two eyes should be superimposed on the one card.

The same procedure is repeated, using the opposite eye behind the prism, thereby obtaining a record for each eye.

By means of the relative displacements, the amount of deviation from normal co-ordination is measured, and the deviation can be definitely apportioned to each eye. The effects of the ductions of spherical and cylindrical errors of refraction, are shown in the shape and size of ambits described, and records of the critical positions in which one eye suspends vision may be investigated.

An interpretation of these charts is easy to the constant observer. I fear some of my readers may find them difficult. For the sake of clarity I will describe Chart A in detail; the chart is that of a clerk who has got vestibular nystagmus; he has never worked in a mine. The left eye shows 3·25 prism dioptres of hyperphoria, the right eye shows 2·75 prism dioptres of hypophoria, in addition, it

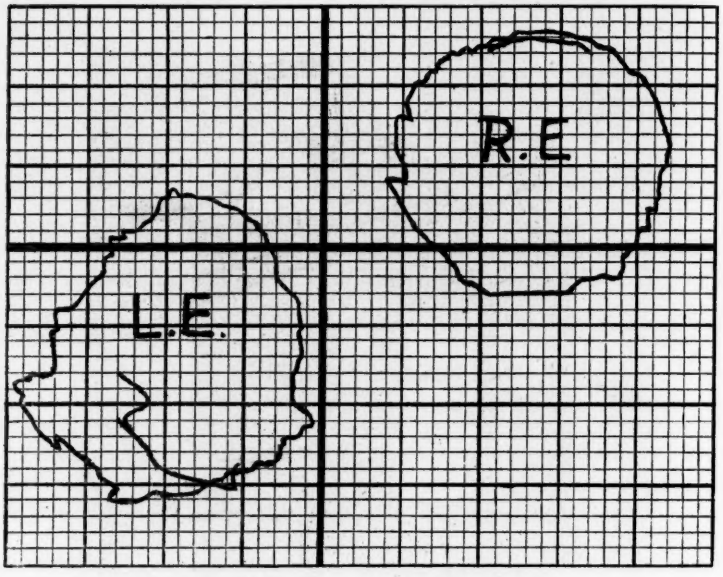


CHART A.

shows about 5·0 prism dioptres of exophoria. This chart was taken without glasses; he has 2·0 dioptres of hypermetropia. It was found that when wearing 2·0 D. correction with a 3·25 prism base down right eye and 2·75 prism base up in left eye, that his hypo- and hyperphoria were corrected and exophoria much diminished; these glasses were prescribed, his eyes are comfortable; slight alterations are made from year to year.

Chart B shows esophoria, which is most marked in left eye; owing to failure of fixation due to fatigue and muscular spasm, he could not complete chart in left eye. (Case of miners' nystagmus).

Chart C shows marked oscillations, hyperphoria in the left eye, in right eye exophoria.

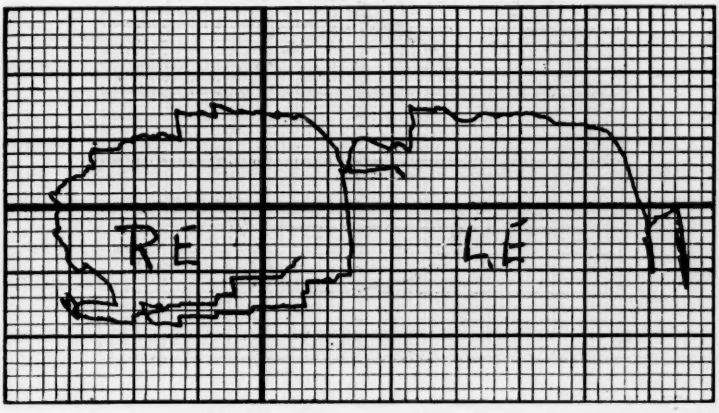


CHART B.

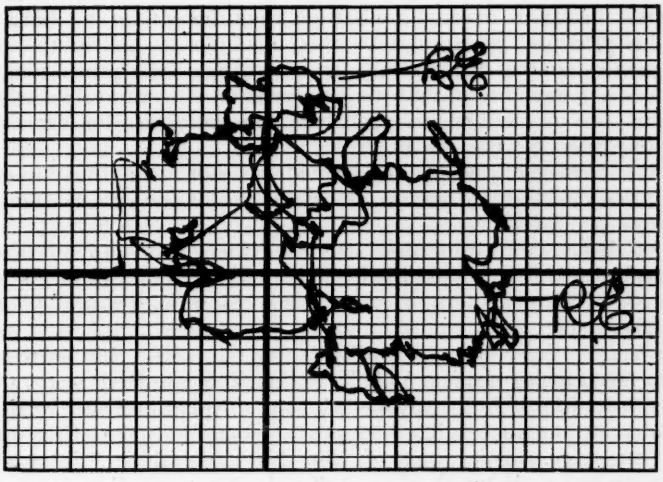


CHART C.

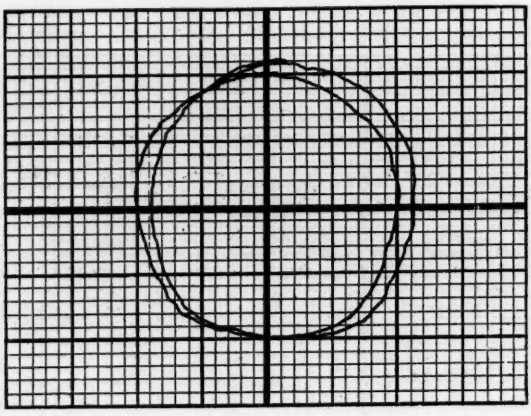


CHART D.

Chart D.—Normal chart.

In nearly every case of nystagmus, I have found with this instrument that a latent squint of some type is present. The patient in Chart C had more marked oscillations than the patient in Chart B.

The principal advantage of this machine to an ophthalmic surgeon is that it demonstrates in which eye the squint is most marked. I have found that the patient is most comfortable, when prisms are prescribed in each eye, in ratio to the error as demonstrated by the charts.

The presence of phorias in nearly all cases of nystagmus favours my theory of the mechanism of production of the disease, which is discussed later.

In a bad case of nystagmus, after the patient bends up and down several times, it is impossible to take a chart; as he cannot fix the objective owing to vertigo, muscular inco-ordination and photophobia.

Effect of injections of Bulbocarpine C_{19} H_{19} NO_4.—In the *Acta Oto-Laryngologica*, Vol. XIII, fac. 2, Sture Berg states that after injection of bulbocarpine 0·1 grm., nystagmus and vertigo, if labyrinthine in origin, disappear. Sometimes the effect lasts for one day. Injections of the drug in rabbits, in whom nystagmus was induced, showed that the drug acts directly on the vestibular nuclei.

This pronouncement induced me to try its effect in miners' nystagmus. In some cases it had no effect, in others blinking and oscillations ceased for several hours—generally, the patients said

their nerves were " steadier "; it had no effect in diminishing vertigo or headache. Oscillations could be temporarily provoked by bending.

The effects of the drug passed off completely in every case in 24 hours, and sometimes in a shorter period.

I cannot vouch for Dr. Sture Berg's suggestion that this drug acted on the vestibular nuclei, I presume it is correct, but if it does not act on these nuclei, it would show that there is some association between oscillation, lid spasm, and the efferent labyrinthine stimuli.

In two cases of ocular nystagmus due to corneal nebula I gave injections of this drug; it did not affect the oscillations.

Causation of Nystagmus.—I am of opinion that the primary cause of nystagmus is deficient illumination, and the principal secondary cause, is malposition at work. I shall endeavour to explain why the statistics of the disease are apparently in disagreement with my opinion. In the pits which I investigated, the fresh cases on compensation were 0·22 per cent. of the workers employed from 1909 to 1920; whereas, from 1921 to 1929 they were 0·41 per cent., yet in the interval the lighting had improved. In the former period oil lamps were principally in use, with a C. P. of about 0·5 at the beginning of the shift, whereas the electric lamp yielded about 0·85 C. P. at beginning of shift and 0·5 at end.

How can these statistics be accounted for; I have found by experiment on myself, that I take five minutes longer to become dark adapted with an oil lamp than with a 1 C. P. electric lamp; and that with a 4 C. P. lamp I become adapted in one-sixth of the time which it takes me with a 1 C. P. electric lamp.

The better the illumination, the less dark adaptation is required, and consequently a shorter period is required. With an oil lamp on a level with my hips at a distance of five feet from the coal face, I felt, when dark adapted and looking at a portion of coal face six feet high, that I was using my peripheral vision; the coal face was not clear, there was little contrast. With a 1 C. P. electric lamp at the same distance, I felt that I was using perimacular or perhaps macular vision; with a 4 C. P. lamp at the same distance, I was confident that I was using macular vision.

I concluded that, in the case of the oil lamp, I was using peripheral vision, and, with the 4 C. P. lamp, I was using central vision from experiments performed in a coal level. I found with the 4 C. P. lamp on walking into the coal face, which was 40 feet from the daylight entrance, that I could view the coal (in dark stall) nearly as distinctly when I looked at it first, as I could after being there ten minutes; whereas, with the oil lamp I had to become dark adapted before I could get a fair view of the face. I found with the 4 C. P. lamp, that I could get the clearest view of

the coal face when I accommodated and concentrated, with lids slightly closed; whereas with the oil lamp, I got the clearest view with my lids open wide. I was also conscious that I was not accommodating, I was subconsciously endeavouring to give my peripheral vision a chance of attaining its best results, *i.e.*, by lack of accommodation, and poor illumination, my pupil was dilated and as a result the most was made of the bad illumination.

I have observed colliers working in good illumination, their eyes have an appearance of concentration, their pupils are not widely dilated, they are obviously using central vision. I have observed men working in bad light, due to having their portion of coal face in shadow; their eyes have that wide open appearance, which leads one to conclude that they are using peripheral vision, and their pupils are widely dilated.

From these observations I have concluded that men working with oil lamps, work altogether with peripheral vision unless the light is very near the coal face, which is mostly not practical.

With 1 C. P. electric lamps, at the beginning of the shift perimacular vision is probably used, whereas towards the end of the shift when light is bad, peripheral vision is used; when a man looks at his lamp the after images are produced by macular stimulation.

With a 4 C. P. alkali lamp, when the lamp is at a reasonable distance from the coal face, macular vision alone is used throughout the shift as the candle power is nearly as good at the end of the shift as it was at the beginning. Macular vision is also used with good cap lamps.

I have compared the paracentral visual acuity of colliers with my own; in all cases the photopic central vision was 6/6. With the dark adapted eye in bad illumination, I have endeavoured to describe the detailed outlines of a portion of coal face, and compared them with the colliers. I concluded that their trained peripheral vision was far superior to mine; in other words, their trained rod vision was twice as good as my untrained rod vision.

In formulating my theory as to the causation of nystagmus, I will adhere strictly to physiological facts and theories, as nystagmus is a non-organic disease of the central nervous system.

We know that at the macula there are only cones present, and that each cone has its own nerve, in the perimacular area there are principally cones and a few rods, in the periphery of the retina there are rods only, several rods have only one nerve connection. Cones are stimulated directly by light, there are photochemical changes; rods are stimulated by the visual purple which has been bleached by light, and a form of optogram sensation passes along the nerve.

The tortoise, which can only see during the day, has got only

cones, and the owl, which sees only in bad light and in the dark, has only rods. The rod vision of the owl is far superior to the rod vision of human beings, because there is in proportion to size of retina, much more visual purple, and each rod has its own nerve ending; in other words, this night eye is adapted for form vision.

The human eye in its periphery is not adapted for form vision, yet the underground workers have endeavoured to adapt it, and in 25 per cent. of cases they have failed, to the extent of developing nystagmus of slight or marked degree.

The illumination with a good oil safety lamp is about 0·60 at the beginning of the shift, but this does not indicate the amount of light available for the worker, which is dependent upon the distance of the lamp from the coal face, and the amount of light which is reflected from the coal face If a lamp of 0·5 C. P. is suspended six feet from the coal face, the illumination of the coal face is about 0·014 C. P., 80 per cent. to 90 per cent. of this is absorbed by the coal face, so the collier works with about 0·003 C. P. Elsworthy in his investigations has found that where there is much gypsum in the coal, and consequently good reflection of light, there is little nystagmus, and *vice versa*.

As a result of this defective illumination, the collier works with peripheral vision; he is trying to defeat nature, the periphery of the retina was never intended to be used for eight hours each day for form vision.

One of the first symptoms of nystagmus is defective vision in twilight: some men say that they are nearly blind in twilight and that they cannot see the coal face as well as they used to.

I suggest that this is probably due to two causes:—

(1) The stratum pigmentum produces visual purple. As a result of continuous overproduction these cells become defective, and nearly cease to secrete altogether, or they secrete a visual purple which is too diluted, and ceases to stimulate the rods on exposure to light; or,

(2) Normally, several rods have only one central nerve connection, and continuous use provokes fatigue and consequently poor transmission of impulses. The owl has excellent rod form sense, but there is one nerve to each rod.

In the normal person, in good light there is a very definite ratio between accommodation, convergence, and size of pupil; when a person converges his eyes, he also automatically accommodates and his pupils are contracted.

I have noticed myself, when walking through a room which is practically devoid of light, that in order to avoid striking articles of furniture, it is best to keep the head erect and the eyes wide open, and to look straight in front without accommodating; the

result is, the pupil is dilated, and the maximum amount of available light is falling on the periphery of the retina.

I have watched colliers at work in bad light; their pupils are widely dilated, the eyes are wide open, they are apparently accommodating very little; yet there is marked convergence.

My eyes are, of course, untrained for this occupation, I have endeavoured to top cut coal under the same conditions of illumination, when dark adapted; an observer has told me that my pupils were contracted, my lids were slightly closed; I was evidently accommodating, converging, and my pupils were contracted, all three were in normal proportion.

Judging from a subsequent conversation with the collier whom I replaced for a few minutes, I could see the coal face nearly as well.

My observation on this is that the collier subconsciously converged more than he accommodated; because, if he accommodated in equal ratio to his convergence, miosis would have resulted, and he would receive fewer reflected light rays and have less peripheral retinal stimulation, and consequently diminished peripheral visual acuity.

If this occurs as I suggest, much of the motor stimulation of the iris sphincter and ciliary body must be subconsciously inhibited, whilst the motor stimulation for convergence is normal or increased.

The third nerve is practically in total control of these three mechanisms. We know that the third nerve nucleus has special localized areas in control of these various mechanisms; so I presume it is quite possible for the miner to suppress or stimulate these various areas subconsciously.

On the other hand dilatation of the pupil may be due to increased stimulation of the sympathetic nerve through its dilator pupillae fibres, this would account also for the retraction of the lids; accommodation and convergence may be acting normally.

The visual acuity of the periphery of the retina diminishes as the pars ciliaris retinae is approached; there are no special areas of fixation; it is possible that, as one area of visual purple is bleached, the form acuity of vision in that portion diminishes temporarily, and that another area is used and as a result the musculature of the eye is constantly altering the areas of fixation; so the amount of nervous energy used would be great. The muscle tonus required for these suggested movements would be of an oscillating type; this may partially account for the oscillations which occur in this disease.

As I have previously stated in my paper, central vision is also affected even in mild cases without oscillations; the visual acuity is rarely better than 6/12, in very acute cases of nystagmus the patient may only be able to count fingers a few feet distant. In

cases who can read 6/12, it is noticed that they pick out the letters of the 6/24 line slowly, each letter has apparently to be fixed with a great effort. Starling states that "fixation is partly a voluntary and partly a reflex effort." I suggest that the difficulty in fixation is due to alterations in the reflex portion of this mechanism, which is caused by retinal fatigue, and that diminished central visual acuity is due to retinal and cerebral fatigue.

When the 1 C.P. electric lamp was introduced, those who were confident that defective illumination was the causation of the disease were hopeful that it would diminish, but it increased considerably.

This increase was probably due to two factors, principally,

(1) The intrinsic brightness of the 1 C. P. electric plain lamp is about 200 times greater than that of the oil lamp; although the increase in illumination as compared with the oil lamp is only ½ C. P. I suggest that the increase in glare causes marked after images, and consequently there is pronounced retinal irritation; as a result, many latent cases have become sub-acute or acute cases.

(2) When the lamp is near the working area the worker is probably using his perimacular vision, whereas, when the light is distant from the working area he is using peripheral vision. This variation in retinal fixation provokes marked fatigue.

Physiologists inform us that stimulation of the following areas provokes movements of the eyes:—

(1) Semicircular canals when stimulated cause conjugate deviation of the eyes; head movements are the normal stimuli.

(2) Stimulation of the median third of the angular gyrus causes both eyes to be turned to the opposite side, if the gyrus on the right side is stimulated, there are conjugate movements of the right internal rectus (third nerve) and the left external rectus (sixth nerve). The angular gyrus is also connected with the frontal and occipital lobes, so that the voluntary movements, and also the reflex movements associated with light stimulation can be carried out.

(3) From the optic tracts, all visual impressions go to the anterior corpora quadrigemina the external geniculate bodies and the pulvinars of the optic thalami. The optic thalamus and external geniculate body convey visual impressions, the anterior corpus quadrigeminum does not. Stimulation of the anterior corpus quadrigeminum provokes movements of the eyes and head; its function is concerned with the co-ordination of visual impressions and movements, with the movements of other parts of the body, and especially with those associated with the mechanism of the labyrinth and cerebellum.

Horsley concluded that the cortex of the cerebellum must be

regarded as an afferent receptive centre, from which axons pass to the ventrally placed efferent nuclei, viz., nuclei dentatus, fastigius, emboliformus, Deiters; stimulation of these nuclei provokes movements of the head, eyes, and body.

Although these various areas are capable of producing efferent impulses which can move the eyes, and in some cases, other

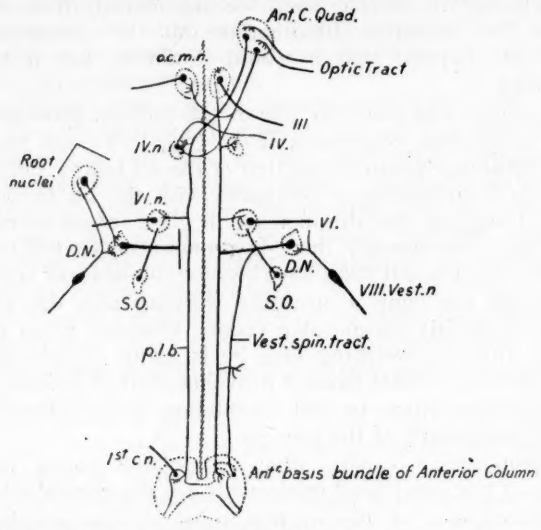


FIG. F. Diagram of connections of posterior longitudinal bundle.

Ant.C.Quad. anterior corpus quadrigeminum; oc.m.n, oculo-motor nucleus; IV.n, nucleus of fourth nerve; VI.n, nucleus of sixth nerve; D.N, Deiters' nucleus; S.O. superior olive; VIII. Vest.n, vestibular nerve; p.l.b, posterior longitudinal bundle; 1st c.n, first cervical nerve.

portions of the body musculature, it is necessary that these stimuli be co-ordinated. Starling states: "This multifarious intercourse which is taking place continually between the eye centres and those for the movements of the body and between the afferent impressions from the eyes and those from the semicircular canals and the proprioceptive system generally, is effected to a large extent through the intermediary of the posterior longitudinal bundle which extends throughout the mid and hind brain, and in the spinal cord becomes continuous with the anterior horn. Receiving fibres above through the anterior commissure from the optic thalamus and from the superior corpora quadrigemina, it is associated in its course with the three motor nuclei which give origin to the nerves supplying the eye muscles.

" Fibres enter the posterior longitudinal bundle from the auditory system, and from the superior olive, and connections are also established between this bundle, the facial nucleus and the nucleus of Deiters representing the central station of impulses from the labyrinth." The general connections of the bundle are shown in Fig. F.

The posterior longitudinal bundle is the tract by which one part of the brain finds out what another part of the brain is doing with reference to muscular actions; it is a clearing house whose principal function is to assist in regulating muscular co-ordination and stimuli.

I suggest that miners' nystagmus is a non-organic disease, whereby the co-ordinate movements of the body, and particularly the eyes have become inco-ordinate, due to altered afferent impulses received from the eyes and the internal ear, and consequently altered reflex efferent impulses are transmitted to the musculature. These efferent impulses are altered in frequency and amplitude, and as a result, the normal tone of the muscles is altered. In order to adapt the eye to bad illumination, the efferent sensations travelling to the iris sphincter and ciliary muscle are inhibited, probably the sympathetic fibres are stimulated, the stimuli producing convergence are augmented and, as a result, the amount of nervous energy required for inhibition and stimulation is much increased. The peripheral visual apparatus which is being used for form vision becomes fatigued; the oculomotor system, owing to abnormal inhibitions and stimulations, also becomes fatigued and perhaps disorganized. As a result of these altered sensations in the visual apparatus, oculomotor system and internal ears, the co-ordinating function of the posterior longitudinal bundle is very much affected.

My investigations of the internal ears in nystagmus, have shown that alteration in sensation occurs in both ears. I suggest that this is due to

(1) As a result of altered visual afferent impulses, and efferent oculomotor impulses, the internal ear receives abnormal afferent impulses from these areas, and its reflex efferent impulses are consequently altered.

(2) The position of the collier at work, is also a source of irritation to the labyrinthine system. Crum Brown has demonstrated " that while one canal was affected by, and transmitted, the sense of rotation about one axis in one direction only for complete perception of rotation in any direction about any axis, six semicircular canals were required, arranged in three pairs, each pair having its two canals in the same plane and with their ampullae turned in opposite directions. Each pair must thus be sensitive to any rotation around an axis, at right angles to its plane, the one

being influenced by rotation in one direction, the other by rotation in the opposite direction." In the semi-reclining and the full reclining position, the head is in an abnormal position; in right-handed men the lambda approaches the right shoulder—the macula of the vertical canals are receiving the maximum stimulation. In normal individuals, it is not customary to test the vertical canals unless it is specifically indicated; because vertigo is often produced, which may last for a day, and labyrinthine nystagmus is pronounced. The abnormal position of the collier, and the impulses provoked by head movements and the concussion of mandril strokes, must be a great irritant to the vertical canals in particular. Evolution has not fitted the human being to do arduous work in this abnormal position; the strain on the labyrinthine system must be very great. It is an admitted fact that the narrower the seam the greater the nystagmus incidence.

We know that the functions of the saccule, utricle, and semicircular canals are to maintain equilibrium, to give information of the body in space, and they exert a tonic action on the body musculature; normally, the tonic action of one labyrinth balances that of the other. Injury to the saccule or utricle of one side causes nystagmus, giddiness, muscular inco-ordination, etc.

I have found in many cases of miners' nystagmus, that there are alterations in the labyrinthine sensation in one ear as compared with the other; I suggest that in this syndrome parts of the labyrinth of one ear are more sensitive than similar areas in the other labyrinth, and consequently altered tone (inco-ordination), vertigo, etc., result. In addition, owing to the alterations in sensation in the various parts, including the ear, the co-ordinating action of the posterior longitudinal bundle is affected.

Bad ventilation favours the production of the disease, because there is maloxygenation of the body, and consequently diminished elimination of the waste products produced by energy in the muscles; consequently these muscles are more easily fatigued, and stronger stimuli are required to perform these movements. The centres controlling these movements suffer equally from accumulation of waste products, and they are consequently more liable to fatigue.

Dr. J. S. Haldane, who is considered by most people the leading authority on mine gases, definitely states that they are not present in sufficient amount to account for this disease. The recent researches of Ivor Lane, which were very thorough, are in accordance with Dr. Haldane's opinion. If nystagmus were due to gas poisoning, one would expect a sudden onset; but it is gradual.

Most underground workers work under similar conditions, yet only 25 per cent. develop nystagmus. Some people probably have more stable oculomotor and labyrinthine systems than others, they

do not develop the disease. The children of nystagmus patients are probably more liable to develop the disease than the children of normal miners.

The mechanism of causation which I have suggested, refers to colliers; it can be adapted to account for the disease amongst other workers also, *e.g.*, timbermen, hauliers, etc.

Recommendations

Illumination.—The reasons of the increase in incidence since the introduction of the 1 C. P. electric lamp probably are, that there has not been a sufficient increase in candle power to insure the use of macular vision at work, and, also that increase in the amount of glare has been out of all proportion to the increase in the amount of illumination; particularly with the plain glass electric lamp. It must be remembered that the electric lamp, at the end of the shift and the oil lamp at the beginning of the shift are both about ½ C. P.

I would recommend

(*a*) The ideal lamp is the cap lamp, but most workers in this area are antagonists to it, because it provokes headache, it is continuously shifting, and the accumulator around the waist is a source of constant annoyance. I have worked recently with a modern one part electric lamp; it seemed ideal.

(*b*) The alternative to the cap lamp is the 4 C. P. electric lamp, the advantages of which I have previously stated. German pits, where these lamps are used, have recently been investigated by Prof. Dr. M. Bortels, Senior Ophthalmic Surgeon, The Eye Clinic, Dortmund, and Dr. Knepper, Essen Bredency. They state that the incidence of the disease has diminished considerably. I feel confident, if this type of lamp were used, that the incidence of the disease would diminish considerably in England, as it has done in Germany.

(*c*) All lamps should be frosted, and should have a slight green tint in addition.

(*d*) Going to, and returning from work, an opaque shade should be fixed to the pillars on the back of the lamp to avoid glare; those who do not adhere to the regulation should be fined.

(*e*) Flood illumination should be used at machine faces when possible.

(*f*) Although ventilation is good in modern pits, it must be remembered that the incidence rate is highest in portions of seams which are badly ventilated; an endeavour should be made to improve the ventilation generally. Better ventilation will mean more coal production.

(*g*) The sons of men who have been known to have nystagmus should not be employed underground.

(*h*) Men returning to underground work after an attack of nystagmus, should not be given colliers' work in the beginning; and when they are given a place it is advisable that the seam should be wide and the ventilation good in their working areas. I realize that this may be a difficult matter for the management to arrange.

(*i*) Suitable glasses, either for the prevention or cure of nystagmus are of little avail. Underground, where he requires his glasses most, the miner cannot use them. As a result, men who wear glasses off duty often find the strain greater underground than they did before wearing glasses; this occurs particularly in the case of hypermetropes whose accommodation is rested to a certain extent with glasses.

(*j*) Men with nystagmus would be well advised to change their occupations if possible.

(*k*) Many of the continued cases from previous years are neurasthenics who would be better doing light employment; they would gradually regain their confidence.

(*l*) Certifying surgeons should be ophthalmic surgeons, given discretionary powers to decide which cases are, or are not incapacitated, and for what type of work they are suited. Should the worker disagree with the certifying surgeon's opinion, he should have access to examination by the ophthalmic medical referee.

(*m*) Contested cases should be decided by a conciliation board whose personnel should include a member of the legal profession in the chair, and an ophthalmic surgeon.

(*n*) Men who have been on compensation, should be given work by the colliery where they were incapacitated.

(*o*) Better illumination on main roadways, stone dusting, whitewashing, etc.

(*p*) Underground workers who are not taking full advantage of the illumination, *e.g.*, light in bad position, too far from coal face, etc., should be reprimanded by officials.

Since completing this investigation, I have received information from collieries where the 4 C. P. electric lamp has been used exclusively in underground districts.

Miners who have used the lamp for a month state that it has all the advantages which I have previously stated in my paper. In addition, I am informed that the glare of other men's lamps, going to work or in their district, is not annoying. Some men say that they do not move their lamps three times during the shift, owing to the excellence of the illumination, and that their coal production is better.

ANNOTATION

Corneal Grafts

It is said of Robert the Bruce that, noticing the spider so well known in folk-lore succeeding, after six attempts, in fixing a thread, he remarked " Now shall this spider teach me what I am to do, for I also have failed six times." For perseverance in an apparently almost hopeless task the spider is worthily rivalled by Mr. Tudor Thomas, whose efforts to obtain clear corneal grafts have lasted nine years. For this long period Thomas has fought against the technical difficulties of grafting one piece of avascular tissue into a similar piece of tissue in such a way as to retain transparency. In seven rabbits, operated upon by the latest and most successful technique, all the grafts healed: one was opaque, one showed a small central clear area and the remaining five were transparent or nearly so. It is true that the history of corneal transplantation is mainly a history of failure and it is true that Thomas's grafts were homoplastic, a method more likely to succeed than when heteroplastic grafts must be used, yet, in spite of all the lions in the path Thomas's work is one of constant progress in the surgical technique of an operation in which everything is against the surgeon. Viewing past efforts of science of all kinds in perspective, even during our own generation, we see that success generally follows effort and we may reasonably hope that what Thomas has succeeded in doing in the case of a rodent may ultimately become one of the many surgical successes when applied to man. Those who have seen Thomas's rabbits will undoubtedly share this hope: the photographs reproduced in the *Lancet* do no sort of justice to the original rabbits.

REFERENCE

Thomas, J. W. Tudor.—Successful grafting of the cornea in rabbits. Hunterian Lecture, *Lancet*, February 14, 1931.

THE INTERNATIONAL ASSOCIATION FOR THE PREVENTION OF BLINDNESS

THE Second Annual Meeting of the Board of Governors of the International Association for the Prevention of Blindness was held on October 10, 1930, at the Palais des Académies in Brussels.

The President, Prof. de Lapersonne, was supported by the members of the Executive Committee and of the Bureau of the Secretariat, and there were also present representatives of many

sympathetic societies, which have become affiliated to the Association, together with a number of well wishers.

The morning of the 10th was occupied by administrative matters, and in his presidential address, Prof. de Lapersonne stated that the work of the Association in this, the initial stage of its career, had been conducted on three main lines, as follows:—first, in the endeavour to find people who were in sympathy with the work and who might help; secondly, in the preparation and issue of a world-wide appeal signed by all the members of the Executive Committee, together with plans for the organization of national committees; and thirdly, in the study of several medico-social problems which come within the compass of the programme of the Association.

With reference to the first, many people had come forward spontaneously with offers of help, whilst support and approval had been received from different countries.

Special mention was made of the valuable assistance given by the National Society for the Prevention of Blindness of the United States through its representative, Mr. Lewis Carris.

The League of Red Cross Societies had given much hospitality, notably on the present occasion, which was that of the XIVth International Conference of the Red Cross.

Amongst the various associations and scientific bodies which had declared their support were the Valentin Hauy Association, the French Society of Ophthalmology, and the Academy of Medicine of Paris.

Her Royal Highness, the Duchesse de Vendôme and the French Minister of Health had granted their patronage, whilst quite recently a sum of 10,000 francs had been granted by the Ministry.

The world-wide appeal, signed by all the members of the Executive Committee, had been drawn up and would be made at a suitable time, but, meanwhile, it was suggested that national committees should be created in the countries which have joined the Association, with general instructions for work on its behalf.

Under the third heading, an enquiry was being made into industrial eye accidents by various oculists practising in industrial areas.

In France, this work is being carried on in conjunction with the General Insurance Committee which includes all the insurance companies of that country and has already yielded much valuable information.

A report on the question of sight saving classes for children has been drawn up and presented to various public bodies, and further work in this direction is being carried out.

Finally, the Association is represented with voting rights on the

Executive Committee of the Anti-Trachoma League, so that these two bodies will work together without trespassing in any way on their various spheres of action.

In conclusion the President deplored the loss of Prof. Axenfeld, a member of the Executive Committee.

The General Secretary, Dr. Humbert, then presented his report, in which he referred to the difficult time financially in which the Association had come into being, and it was on this account that the issue of the world appeal had not been generally made but issued only to a restricted number of well wishers. The response to this, almost wholly from members of the medical profession, had been generous and very gratifying, considering the small number of people concerned.

Especial mention was made of the invaluable help rendered by the National Society for the Prevention of Blindness of the United States, which has voted a contribution of 1,000 dollars and, in addition, a regular annual subscription.

Besides the support from the various societies to which the President had referred, he emphasized the great help which the Red Cross rendered.

Twenty-three national Red Cross societies had now adhered to the Association, and amongst the Presidents of these, who had become Founder Members of the Association, were H.R.H. Prince Charles of Sweden, the Hon. John Barton Payne (U.S.A.), General Pau (France), Mr. Cremonesi (Italy), and others.

Finally, collaboration with the Junior Red Cross, whose members number over twelve millions, was being planned.

In conclusion, Dr. Humbert laid the greatest stress on propaganda as the key-note not only in the work of the Association but in creating the means by which its work can be carried on.

On the unanimous adoption of the two reports, Mr. Lewis Carris spoke on the work of the American Society for the Prevention of Blindness, and was followed by Mr. Milsom, of the Junior Red Cross Society, who outlined some of the activities in which his Society had been engaged, and showed how its collaboration with the Association had already been established in regard to school work.

An extremely interesting address was then delivered by Mr. C. J. Henderson, the President of the All India Blind Relief Association (the Green Star Society), in which he showed clearly the enormous field of work that lay waiting in India. Blindness in this country is, according to more detailed enquiry, something like three times the amount that the official census returns give and must total quite a million and a half, much of which can be prevented.

The conditions in China were then described by Dr. Lossonaru of the School of Medicine, Tientsin, and a Vice-President of the International League for the Prevention of Blindness in China.

It was impossible not to be impressed with the need for help in this country. Dr. Lossonaru, who has been in practice in Tientsin for 17 years, has worked with the above-mentioned League since its formation in 1924. His investigations show that half a million have lost their sight in China from small-pox alone, constituting 35 per cent. of the total number of blind. Xerosis from faulty hygiene ranks next, although it must be presumed that this is a temporary cause only. Trachoma is the third numerical cause, followed by syphilis (50 per cent. of the population in the town are infected) and gonorrhoea, whilst a common cause is injury to an eye by the pricking of any part of the organ by a relative or quack. The existence of the latter is not surprising when it is considered that there is only one Chinese physician with an Occidental training for every 200,000 inhabitants.

To combat this state of affairs there are, in Tientsin, four dispensaries where vaccination, anti-syphilitic treatment and ophthalmic treatment are being carried out.

There are 191 dispensaries in the interior, which do their best on similar lines in charge of missionaries, who receive eye drugs and vaccine, etc., free.

A communication by Mr. Reinhard describing the causes of blindness in Latvia followed.

The President, Secretary-General and the members of the Executive Committee were then re-elected, together with Prof. von Szily, representing the German Red Cross in the place of Prof. Axenfeld, deceased, and Dr. van Duyse as representative of the Belgian Red Cross.

This concluded the morning session.

The afternoon was mainly occupied by scientific papers, the first of which was the report by the President, Prof. de Lapersonne, giving the results of an inquiry into industrial accidents made by the Association.

The information obtained so far has emphasized the considerable part played by these accidents as a cause of unilateral or total blindness, and the proportionate increase with the progress of industry, as might be expected.

The work is being carried on in conjunction with the Committee of French Insurance, and is directed on three main lines, namely:—(1) to examine by category and order of importance the main causes of eye accidents in industry, (2) the method of prevention against each cause, and (3) to consider the psychological problem of ensuring that the preventive method be carried out. French oculists in suitable areas have examined several

thousand cases and conclude that 25 per cent. to 35 per cent. occur in the metallurgical industries.

The seriousness of penetrating injuries, both with and without the presence of a foreign body in the globe, is shown by the fact that, in from 50 to 60 per cent. of the cases collected, there was functional loss of the wounded eye. Owing to pre-existing infection of the lids, so prevalent amongst natives in Northern Africa, a minor injury has frequently led to working loss of the eye, and this stood as a strong plea for an ophthalmic examination of the worker to be made before employment.

As no ideal method of protection for the eyes had so far been produced, it was suggested that a commission of surgeons and engineers should study this question. The problem of lighting in industry generally was also mentioned.

The paper was well received and was discussed by Mr. Lewis Carris of the American National Society for the Prevention of Blindness.

A contribution by Mr. B. Cridland (Great Britain) was read introducing a simple method of protection against minor injuries of the eye, which had been found of considerable value in Great Britain. The results of an investigation into this class of injury from an economic point of view were also given.

Discussion followed in which Prof. von Szily (Germany) Dr. Humbert (Secretary General), the President, Dr. Pundel (Luxemburg) and Dr. Jitta (Health Committee of the League of Nations) took part.

Prof. de Lapersonne then spoke on sight-saving classes for children with defective sight. After paying a well-deserved tribute to the pioneer work of Mr. Bishop Harman, who was the first to establish a class of this kind in 1908 in London, he referred to what had followed in Germany and the United States. The necessity for the establishment of this special education in all countries was emphasized. The principles which would serve as a guide in the organization and management of such classes were summarized in a résumé, largely based on information given by Dr. Redslob, of Strasbourg, who as School Medical Inspector, working in conjunction with Mr. O. Baumann, Director of the sight-saving class, instituted this innovation 18 years ago.

The visual standard for a candidate, for a sight-saving class in Strasbourg, is 2/10, or below, in the better eye, whilst one who sees only " fingers at 1 metre " in the better eye is sent to a blind training institute.

After discussing methods of teaching, etc., Prof. de Lapersonne concluded with a reference to a communication he had received from Dr. August Helia, of Helsingfors, in which that writer made the following wise comment, " In spite of the great usefulness of such

schools for their pupils, the education they have received will only be effective if they can get work which will enable them to earn their living."

Mr. Lewis Carris, speaking from his long experience as a school administrator, gave an account of similar work which was being done in the United States. There they had recognized the need for extending the benefit of this special education to the country children as opposed to those living in towns, the proportion being greater in the former than in the latter, for reasons not yet satisfactorily explained. They had especially endeavoured to enlist the sympathy of the laity in the work, as well as that of members of the medical profession.

Dr. Humbert referred to the International Organisation for the Campaign against Trachoma, which was formed at Geneva on July 26, 1930, an account of which appeared in the *British Journal of Ophthalmology* for October, 1930.

Dr. Wibaut (Holland), the Secretary General of the Organisation, Prof. de Lapersonne and Dr. J. Jitta also spoke; all three emphasized the importance and value of co-operating with the International Association for the Prevention of Blindness and with the Health Organisation of the League of Nations.

The session concluded with an interesting address on trachoma by Prof. Angelucci (Naples) in which he discussed the relationship of trachoma, follicular conjunctivitis and adenoidism.

From the interest generally displayed throughout the meeting, it may be concluded that the Association has made an excellent début.

ABSTRACTS

MISCELLANEOUS

(1) **Collier, James (London).—The diagnosis of frontal tumours.** *Brit. Med. Jl.*, August 17, 1929.

(1) In a very full survey of the subject of frontal tumours **Collier** discusses the value of the ocular signs in diagnosis.

He does not think that conjugate deviation of the eyes is in any way special to the pre-frontal lobes but considers the sign of value in lateralizing the lesion. Similarly he does not consider papill-oedema of any value either in localization or lateralization.

R. C. DAVENPORT.

(2) **Brown, Albert (Cincinnati).—The rôle of unlevel orbits in heterophoria.** *Amer. Jl. of Ophthal.*, October, 1929.

(2) **Brown** gives an account of 50 patients, each of whom had one orbit more than 5·0 mm. above the plane of its fellow and suffered varying degrees of discomfort. He found that the muscle balance of these patients was not always the same at successive tests. If the patient were fresh and untired, the lower eye might be the hyperphoric one, owing to an excess of reserve energy, whereas after fatigue it was usually orthophoric or hypophoric. When examined with the Maddox rod, hyperphoria of the higher eye was found in 50 per cent., orthophoria was present in 30 per cent. the remainder showing hypophoria of the higher eye. After five days of monocular occlusion 96 per cent. showed hyperphoria of the higher eye, and 85 per cent. reported relief of symptoms after 24 to 48 hours of occlusion. When the muscle balance was examined with Maddox rods at reading distance it was found that cyclophoria developed in the 50 per cent. who had hyperphoria before occlusion, the lower eye seeing the line horizontal while the higher eye saw it tilted with the nasal side higher. This cyclophoria was abolished when the hyperphoria was corrected. All the patients were made much more comfortable by correcting three-quarters of their hyperphoria, though six per cent. of them required a later increase in strength of the prisms.

F. A. W-N.

(3) **Loddoni, Giovanni (Turin).—Gold preparations in ocular therapeutics. (I Preparati di Oro in Oculistica).** *Lettura Oftalmologica*, Anno VI, No. 8, October, 1929.

(3) **Loddoni**, besides quoting others, gives his own clinical experiences of a series of cases treated by the intravenous injection of preparations of gold. The cases treated were mainly those of uveal tract inflammations and keratitis, and favourable results are reported. The treatment is not without its dangers, as immediate symptoms of nausea and rise of temperature may develop, while the injection may be followed in a few days by albuminuria.

R. A. GREEVES.

(4) **Giannantoni, C. (Perugia).—Contributions to the knowledge of the sequelae of dazzling by sunlight and by electric light. (Contributo Alla Conoscenza delle Consequenze dell' Abbagliamento da Luce Solare e da Luce Elettrica).** *Lettura Oftalmologica*, Anno VI, No. 8, October, 1929.

(4) **Giannantoni** describes four cases of eclipse blindness, and one of partial central scotoma from exposure to an arc light. He makes the following statements:

1. The visual disturbance follows immediately on exposure to intense light. Although a gradual improvement takes place almost to normal acuity of vision, the patients are usually left with the sensation of slightly misty vision.

2. Fundus changes are not constant.

3. The annular scotoma described by Jess is not constant.

4. Besides the diminution of direct visual acuity, indirect vision may also be affected, and this disability may persist even when central vision is restored to normal.

5. In consequence of dazzling by intense electric light, changes may occur in the macular region, showing as numerous small yellowish spots. Corresponding to this fundus change, there is a partial central scotoma, relative for colours.

R. A. GREEVES.

NOTES

Death

AS we go to Press we much regret to hear of the death of Mr. Percy Dunn, Consulting Ophthalmic Surgeon to the West London Hospital and Editor of the *Medical Press and Circular* and of the *Bulletin of the Fellowship of Medicine.*

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Royal London Ophthalmic Hospital, Annual Dinner

THE Annual Dinner of past and present Students of the Royal London Ophthalmic Hospital was held at the Langham Hotel on Thursday, February 12. The Chairman was Mr. A. H. H. Sinclair, F.R.C.S., Ophthalmic Surgeon to the Edinburgh Royal Infirmary. Among those present were Lieut.-Gen. Sir H. B. Fawcus, K.C.B., D.G., A.M.S., Dr. T. Watts Eden, President of the Royal Society of Medicine, Professors Elliot Smith, Woollard and Lovatt Evans, Sir Walter Fletcher. Sir William Lister, Sir John Parsons, Lady Lister, Lady Cooper, Mr. Theodore Luling, Chairman of the Hospital, Mr. J. Herbert Fisher, Mr. Treacher Collins, Mr. Holmes Spicer, and Mr. K. G. R. Vaizey.

The Toast of the Hospital and Medical School was proposed by the Chairman; Mr. Luling and Mr. Charles Goulden, the Dean, replied. Other toasts were proposed by Mr. R. Affleck Greeves and Mr. R. Foster Moore. Dr. Watts Eden and Lieut.-Gen. Fawcus replied.

The Dean in presenting his report spoke of the improvements that were soon to be put in hand by the Board of Management. The Out Patients department would be much enlarged and marked improvements made whereby the Clinical teaching could be carried out more conveniently.

The school accommodation would also be enlarged as well as that of the library and laboratories. The hospital itself had been enlarged during the past year and there were now wards for private patients, a much-felt need.

In the year under review the number of students working at the Hospital was 160, of whom 98 were new. The number of lectures given amounted to 409 apart from the usual clinical teaching.

In the public examinations the following successes were recorded: D.O.M.S.—At the examinations in February and July, 1930, of the 64 candidates who presented themselves for the complete certificate, 38 passed and of these 26 had pursued their studies at Moorfields. During the same period 87 candidates presented themselves for Part I of the certificate of whom 49 were successful and of these more than two-thirds had received their instruction in the Medical School.

Dr. Russell Brain has been elected Assistant Physician, Mr. Howells, Ear, Nose and Throat Surgeon, and Mr. Winter, Dental Surgeon. Professor H. H. Woollard has been appointed Lecturer in Anatomy.

Mr. Duke-Elder and Miss Ida Mann have, by invitation, visited the United States of America to give a series of lectures. Mr. Tudor Thomas has been appointed Hunterian Professor at the Royal College of Surgeons of England, and Mr. J. H. Doggart has been elected Assistant Ophthalmic Surgeon to St. George's Hospital.

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French Course in Ophthalmology

A COURSE in advanced ophthalmology is announced to be held at the Hôtel Dieu under the auspices of the Faculté de Médecine de Paris from April 17 to May 15, 1931. The course is under the direction of Professor Terrien, who will be assisted by numerous collaborators and will be composed of two parts: (*a*) clinical and laboratory, (*b*) ophthalmic surgery.

The following lectures have been arranged. Ocular lesions in diabetes, by Professor Rathery; radium therapy in ophthalmology, by Professor Regaud; ophthalmic pharmacology, by Professor Tiffeneau; and electro-therapy in ophthalmology, by Professor Zimmern.

The fee for the course has been fixed at 300 francs; further information can be obtained from Professor Terrien.

International Trachoma Prize

THE Royal Hungarian Minister of Public Welfare and Labour offers a prize of 2,000 Swiss francs for an independent work on the aetiology of trachoma. Essays should be addressed to the Eye Clinic, No. 1, Royal Hungarian Peter Pázmány University, Budapest (viii, Mária-utca. 39), not later than June 30, 1931.

Works already printed are eligible for the competition as well as those specially written for the occasion. The jury of award may also consider works not submitted for competition but appearing in print between July 1, 1929, and June 30, 1931. Essays may be written in German, English, French, Italian or Hungarian.

The jury of award, appointed by the Royal Hungarian Minister of Public Welfare and Labour, is composed of A. F. MacCallan (London), Victor Morax (Paris), L. Maggiore (Bari), and Carl Prausnitz (Breslau).

The jury's decision will be announced not later than December 31, 1931.

FUTURE ARRANGEMENTS

1931

April 23-25.—Annual Congress of the Ophthalmological Society of the United Kingdom, in London.
June 5.—Midland Ophthalmological Society, at Cheltenham.
June 12.—Section of Ophthalmology, Royal Society of Medicine. (Annual Meeting).
July 8-11.—Oxford Ophthalmological Congress, at Oxford.
October 6.—Midland Ophthalmological Society, at Birmingham.
December 1.—Midland Ophthalmological Society, at Birmingham.

CONTEMPORARY OPHTHALMIC LITERATURE

American Journal of Ophthalmology. *February, 1931.*

CALHOUN. Observations on the formation of macular star in nonrenal cases.
GIFFORD. A review of the literature on the etiology of acute iritis.
MOORE. Syphilitic iritis.
FINNOFF. Tuberculosis in the etiology of acute iritis.
GOAR. Nodular opacity of the cornea.
FRIEDENWALD, J. S. The contributions of Prof. Ernst Fuchs to ophthalmic pathology.
GRADLE. A statistical analysis of ophthalmic patients.
HALLETT. The prevention of myopia.

Annales d'Oculistique. *January, 1931.*

GONIN. Obliterating cautery puncture for tears in detached retina.
REDSLOB. The development of the vitreous body in the fowl.
PALLARES. A case of double hemianopia with preservation of macular vision from birth.

Archives of Ophthalmology. *February, 1931.*

FAVORY. Haemorrhage into the sheath of the optic nerve.
GOURFEIN. Two new ocular symptoms in oxycephaly or in premature craniosynostoses and their pathogenesis.
BRANBERGEN. Cataract after thyroidectomy.
VILLARD. The practice of teaching ophthalmology in the Latin countries.
MACCALLAN. The marginal fossettes of Herbert and the corneal rosettes of trachoma.

Bulletin de la Société Belge d'Ophtalmologie. *November, 1930.*

BAILLIART. The eye in hypertonus.
ORBAN. The surgery of the sympathetic.
CLAES and DECLERCQ. A case of intra-ocular and corneal foreign body.
COPPEZ. Some cases of intra-ocular foreign bodies and their localization by stereoscopic X-rays.
WEEKERS. ? Mode of action of operations for glaucoma.
WIBO. Fistulising sclerectomy in the treatment of conical cornea.
COPPEZ. Iridocyclitis with rise of tension.
HAMBRESIN. Typical bitemporal hemianopia completely disappearing after application of X-rays. Some reflections on the results of radiotherapy in cases of pituitary tumour.
BADOT. Ocular results of short circuit injuries.
HOONACKER. Effects of removal of the carotid body on the retinal circulation.
FRITZ. The rôle of arterial hardening in the physio-pathology of the retinal circulation.
KLEEFELD. Lateral extraction of cataract without the suction apparatus.
RASQUIN. The prognosis of sarcoma of the choroid.
JAEGER. Retinal tears from traction with consecutive detachment.
GAUDISSART and VAN LINT. The teaching of ophthalmology to doctors in Philadelphia.
STRAETEN. Teaching and development of ophthalmology in Belgium a propos of the plan of creating a special doctorate.

Revue d'Oto-Neuro-Ophtalmologie. *November, 1930.*

TAUSSIG and DOSUZKOV. Permanent conjugate deviation during the course of epidemic encephalitis : particularly the syndrome of conjugate deviation, flexion posture, and contralateral hypotony.
GAUDISSART. Paralysis of lateral movements of the eyes and dissociated nystagmus in disseminated sclerosis.
GAUDISSART and LARUELLE. Graefe's sign as a symptom in cerebral localization.
VAN GEHUCHTEN. Case of lateral paralysis of fixation from a mid-brain lesion.
FROMENT, DECHAUME and COLRAT. Two anatomical observations of paralysis of associated lateral movement.
JEAN-SEDAN. Post-diphtheritic laevogyral ocular paralysis.
BORRIES. Auricular tetany and its connection with ocular tetany.
WORMS and CARILLON. Contribution to the study of oxycephaly.
EEMAN. Thrombo-phlebitis of the cavernous sinus. Bilateral orbital thrombophlebitis following tonsillar abscess.
SENNA. Treatment of inflammation of the lacrymal sac by internal dacryo-cystorhinostomy.

December, 1930.

BARRE, METZGER and KUHLMANN. Study of certain reflexes, especially the oculo-cardiac and induced nystagmus in a case of pathological sleep.

Zeitschrift für Augenheilkunde. *February, 1931.*

ROSENBERG. Diabetes and the eye.
HOFFMANN. The effect of X-rays on the retina.
GUIST. Raised arterial tension and the eye.
PILLAT. Bacteriological examination of the conjunctiva as a means of obtaining information concerning vitamin A deficiency likely to lead to kerato-malacia.
VON PELLATHY. Detachment of the retina and congenital uveitis in three sisters.
VANCEA. Is there an iris symptom complex in tabes and general paralysis?
BLATT. What should true trachoma be called?

Archivio di Ottalmologia. *October, November, December, 1930.*

GALLENGA. Nodular tuberculosis of the subconjunctival tissue of the lids.
——— On a lid reflex from stimulation of the superior laryngeal nerve.
LUGLI. Contribution to the study of epibulbar epithelioma.

Bollettino d'Oculistica. *January, 1931.*

NEUSCHULER. Pemphigus of the conjunctiva.
MARGOTTA. Corneal degeneration of Groenouw.
GUALDI. Clinical and biomicroscopic contribution to the study of the pathogenesis and morphology of electric cataract from the industrial current.
HORNIKER. The value of entoptic examination in affections localized to the posterior pole of the eye.
DE LOGU. Clinical and anatomical contribution to the study of epithelioma of the limbus and its extension on to the cornea.

Lettura Oftalmologica. *November, 1930.*

GUALDI. Retinal haemorrhage in essential hyperpiesis.
BUSACCA. Partial atrophy of the optic nerve and choroid with a pseudo-coloboma of the nerve and of the choroid of traumatic origin.

December, 1930.

GUALDI. Retinal haemorrhage in essential hyperpiesis (*continuation and end*).
——— Contribution to the pathogenesis of spontaneous conjunctival haemorrhage.
PEDICO. Non-specific treatment in ophthalmology.
ADINOLFI. A case of periodic congestion of the conjunctiva and of the mucous membranes of the adjacent sinuses at the menopause.

Archivos de Oftalmología Hispano-Americanos. *January, 1931.*

LAUBER. Professor Fuchs.
GARCIA. My impression of phakoeresis.
MARQUEZ. The reason for the existence of the optic chiasma.
BLANCO. Corneal complications of spring catarrh.
GOMEZ-MARQUEZ. An interesting case of tumour deep in the orbit.
MENDOZA. Anaglyphs.

Revista Oto-Neuro-Oftalmologica. *February, 1931.*

PAVIA. Hypertensive retinitis.